OPTIMIZATION OF THE SAMPLING EFFICIENCY OF EXPLOSIVES DETECTION PORTALS BY THE USE OF FINITE ELEMENT FLUID DYNAMICS MODELING

by

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LIMITED

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ABSTRACT

A fluid dynamics software package has been used to investigate and optimize the characteristics of existing, proposed, and hypothetical explosives-detection portals. The software employs a finite element method. The study demonstrated that in order to process ten persons per minute, as required by the FAA, the slow air-flow layer adjacent to the passenger must be thinner than 0.2 inch. The study also established an optimum direction of the air-flow. Finally, it was determined that baffles, when properly placed, can improve the flow characteristics of the portal.

INTRODUCTION

The detection of explosives concealed on airline passengers continues to be a technical problem for the FAA. Traditional bulk-detection methods such as x-ray, thermal neutron analysis, nuclear magnetic imaging, etc., cannot be used to screen passengers, since these methods present health hazards. Therefore, detection of explosives vapors appears to be the only practical and acceptable method for screening passengers. During the past ten years, several commercial personnel-screening systems have been developed. Most of these systems are capable of detecting the vapors from nitroglycerine and dynamite (ethylene glycol dinitrate), some even have the ability to detect the vapor from concealed TNT. Few, however, can reliably detect vapors from plastic explosives. Detection in an airport-setting is difficult, because the sampling and detecting process must be performed in six seconds, as stipulated by the Federal Aviation Administration. This formidable problem includes four steps: (1) sampling the air around the person;(2) collecting the explosives vapor;(3) transporting the collected vapor to a detection system; and (4) analyzing the collected vapor. Since analysis (step 4) has been developed to a point where further improvements are unlikely in the near term, any dramatic improvements in portal performance must come from the other three steps. Recently, there have been some developments in step 2, collecting the explosives vapor. Most promising have been the efforts of Sandia National Laboratories (silica surfaces), Ion

Track Instruments (continuous rotary trap), and Thermedics, Inc., (coated metal surfaces). Step 3, transport of collected vapors, cannot be improved, except to keep the transport distance as short as possible. A "magic" material for construction of transport and sampling lines has not been developed. Industry efforts, to date, have only shown which materials do not make good sampling and transport lines. This leaves step 1, sampling of the air around the person, as the remaining area for improvement. Since only a limited amount of research has been devoted directly to this problem, the present effort was undertaken to investigate the sampling characteristics of various explosives detection portals. These include a prototype walk-in/walk-out portal, a proposed walk-through portal, a hypothetical walk-through portal, a tapered walk-through portal, and a proposed revolving door portal. Finally, the effects of baffles on the flow profile were examined. All portals were examined using new finite element software called FIDAP 6.0.

FINITE ELEMENT BASED FLUID DYNAMICS MODEL

In the past, a design could be tested only by building a physical model and operating it in the laboratory. Recent advances in both computer technology and computational techniques have made it possible to construct numerical models to evaluate a proposed design. Since a different physical model does not have to be built in order to study every change in the design, numerical modeling tends to be cheaper and faster.

The numerical model used in this study was FIDAP 6.0, developed by Fluid Dynamics International of Evanston, Illinois. FIDAP is a general purpose computer program that uses the finite element method (FEM) to simulate many classes of fluid flows. It is capable of simulating two- and three-dimensional steady-state or transient conditions. The effects of temperature, pressure, and mass transfer can be accurately simulated. The magnitude and complexity of the problem to be studied are limited only by the user's computer capacity and by time constraints. The volume to be studied is divided into many small geometric shapes called finite elements. Figure 1 is a sectional view of a hypothetical explosives portal, divided into a mesh of finite elements; the person being screened is represented by an oval. Since the person is opaque to air flow, finite elements do not need to be generated within the oval. The partial differential equations of fluid flow in the region as a whole are replaced by ordinary differential equations for each element. These equations are then solved by

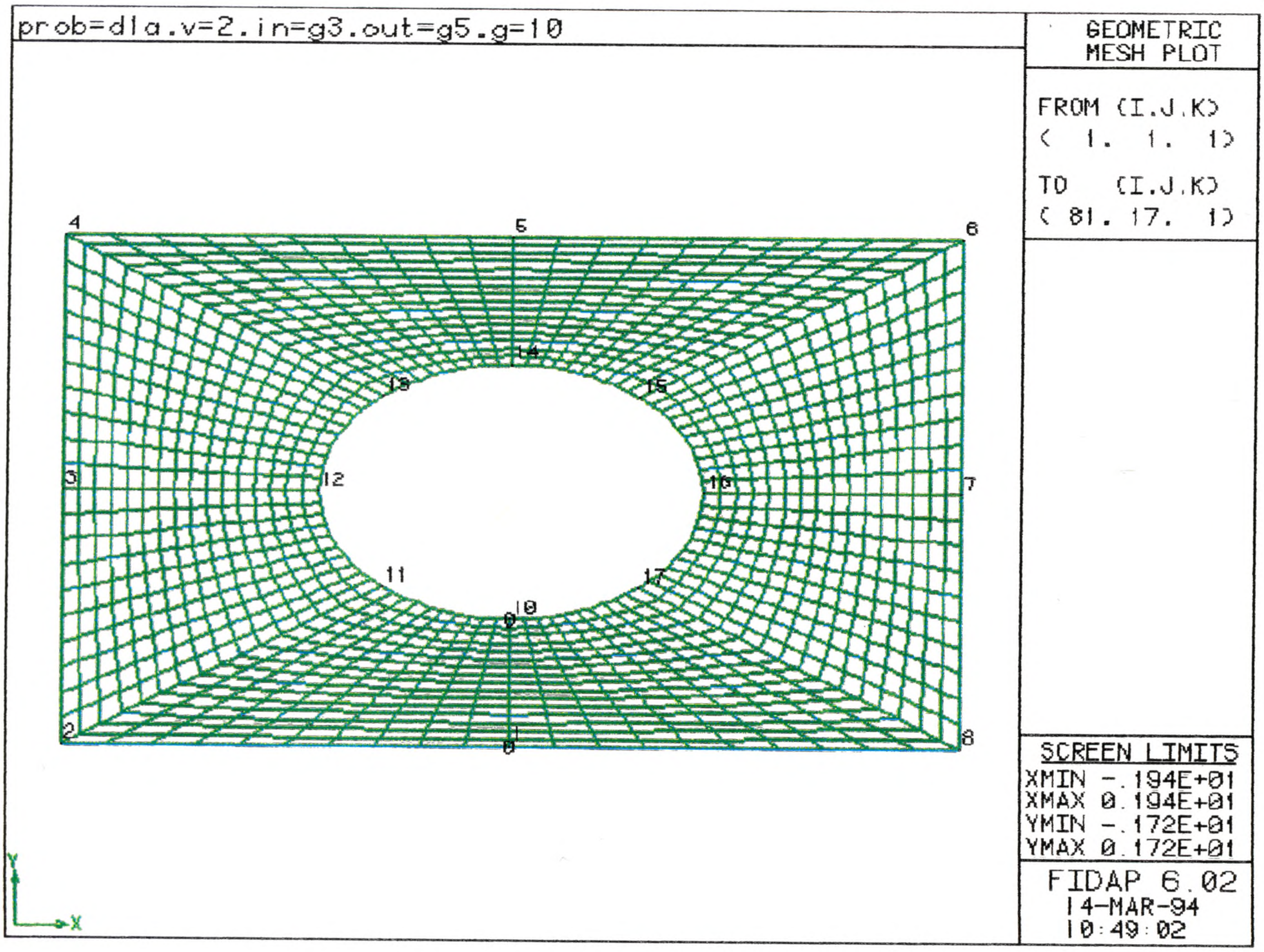

Figure 1. Sample Mesh.

numerical techniques to determine the velocities, pressures, temperatures, and species concentrations throughout the region.

Proper formulation of the problem is crucial in order to obtain meaningful results. First, a mesh must be designed which fits the problem geometry and addresses its special needs. Second, each element of the mesh must be characterized as a fluid element, a wall element, a mass transfer element, or some other type of element. Once the elements are characterized, the proper boundary conditions must be assigned to the mesh. Third, the correct fluid properties must be assigned, such as temperature and diffusivity. Fourth, the problem is deemed steady-state or transient, and a successive substitution or other solution technique is chosen.

CONVENTIONS AND BACKGROUND

When designing explosives detection portals, a primary concern is minimizing the slow-flow zones and wakes. Since the explosives vapor can move no faster than the speed of the air-stream, slow-moving zones inhibit vapor collection. Using fluid-dynamics software, one can model various portal designs and study the effects of modifications on the magnitude of such slow-flow zones. The boundary of the slow-flow layer was deemed to be that part of the flow-profile where the air speed exceeded 0.1 foot per second, because it approximately marks the transition from laminar to turbulent flow. This boundary is important, because mass transfer in the laminar zone is by diffusion only, whereas in the turbulent zone eddy mixing supports mass transfer.

The Figures presented herein utilize the following conventions:

- The legend describes the type of plot.
- British units are used for all plots: length in feet, speed in feet per second, mass flux in pounds of explosives vapor per square foot per second. Concentration is given as a mole fraction.
- Red depicts a maximum value, dark blue a minimum value, and green and yellow intermediate values.
- Flow is from left to right unless otherwise stated.

- The plots all depict a sectional view at one-half of the respective portal height.
- The person is represented by an oval.
- Color contours indicate changes of a specific variable within the portal.
- The Screen Limits represent the dimensions, in feet, of the portal section.

Figure 2 represents a conceptual portal design. The person enters from the left, stops midway, and turns 90 degrees; the air-stream travels from left to right. The legend indicates that the air speed in the red area is at least 1.5 feet per second. It also indicates that the maximum speed is 4.33 feet per second. The other colors represent diminishing air speeds. Of special interest are those areas of the portal where the speed is slowest, especially those adjacent to the person, where the speed is zero, by definition. All such areas near solid boundaries will be termed slow-flow zones. There are four slow-flow zones in Figure 2. The first is the thin layer which occurs at all walls. It would have little effect on explosives vapor collection in a well-designed portal, where the vapor would exit the portal long before colliding with the walls. The second slow-flow zone is adjacent to the stagnation point "A," where the free-stream strikes normal to a surface. The third slow-flow zone at point "B" is similar to those at the walls. The width of this slow- moving layer could be reduced somewhat with increased flow, but the change would be small. Since

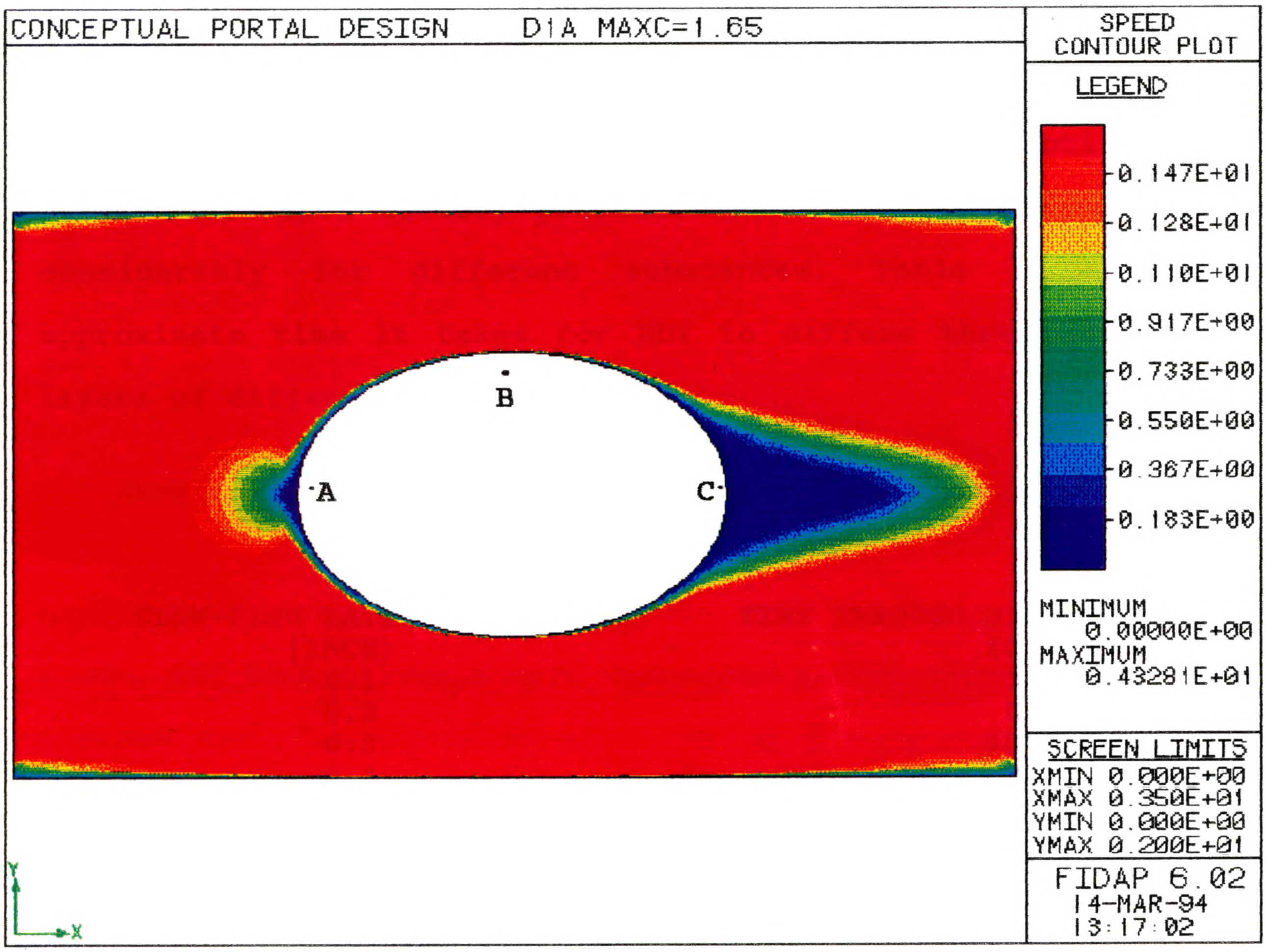

Figure 2. Contour speed plot of a conceptual portal design.

this layer is relatively thin, it does not preclude a rapid mass transfer. The fourth slow-flow zone is the wake produced adjacent to point "C". This relatively large area presents a major obstacle to mass transfer. Not only is the air moving very slowly here, but the model indicates that it is swirling as well. If explosives vapor were to enter this wake it could remain for some time. In an actual case of a concealed explosive, the vapor must diffuse through the slow-flow layer adjacent to the person before it can reach the faster moving free stream, which adds convective forces to the diffusion already present. The rate of diffusion varies considerably for different substances. Table 1 shows the approximate time it takes for RDX to diffuse through slow-flow layers of different widths.

TABLE 1

SLOW-FLOW LAYER WIDTH (INCH)	TIME THROUGH SLOW-FLOW LAYER (SEC)
0.1	1.5
0.2	6.0
0.3	13.5
0.4	24.1
0.5	37.6
0.6	54.1
0.7	73.7
0.8	96.2
0.9	121.8
1.0	150.3
1.1	181.9
1.2	216.5
1.3	254.0

For an acceptable screening rate of at least one person every six seconds, it is seen that the slow-flow layer must be less than 0.2 inch. Therefore, the purpose of the modifications presented in the following section will be to reduce the size of the wake and the width of the low-flow layer at the stagnation points.

RESULTS

Figures 3-16 depict flow conditions for a commercial design and various suggested modifications to improve it. Figure 3 is a contour plot of air entering from the left and right and exiting at the top and bottom. The oval again represents the person. Having dual exits might seem to enhance vapor collection, but in fact hinders it by creating a situation where the air flows along the booth, but then curves toward the exits before it has a chance to contact the person's front and back. In Figure 4 the area around the person is enlarged in order to better view the slow-flow layer, which is thin near the person's sides (point B), but broadens at the person's front and back (point C). Figure 5 is a further magnification of the slow-flow layer. Points "A," "B," and "C" are to illustrate the slow-flow layer thickness at three different locations. From the Screen Limits, the actual magnitude of the various flow areas can be determined. For example, in Figure 5, since XMIN is 5.69 feet and XMAX is 6.21 feet, the plot depicts

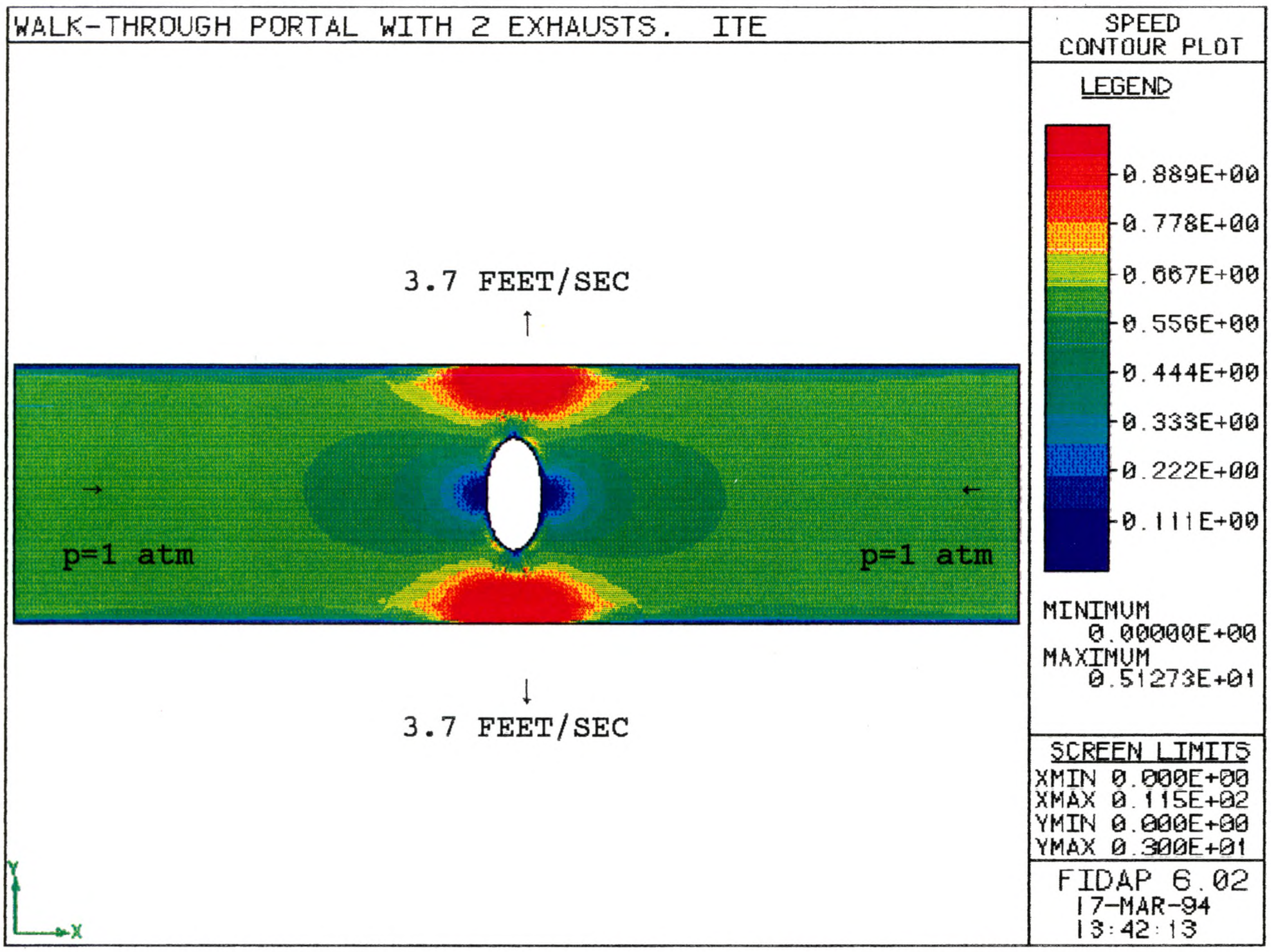

Figure 3: Walk-through portal with dual exhausts.

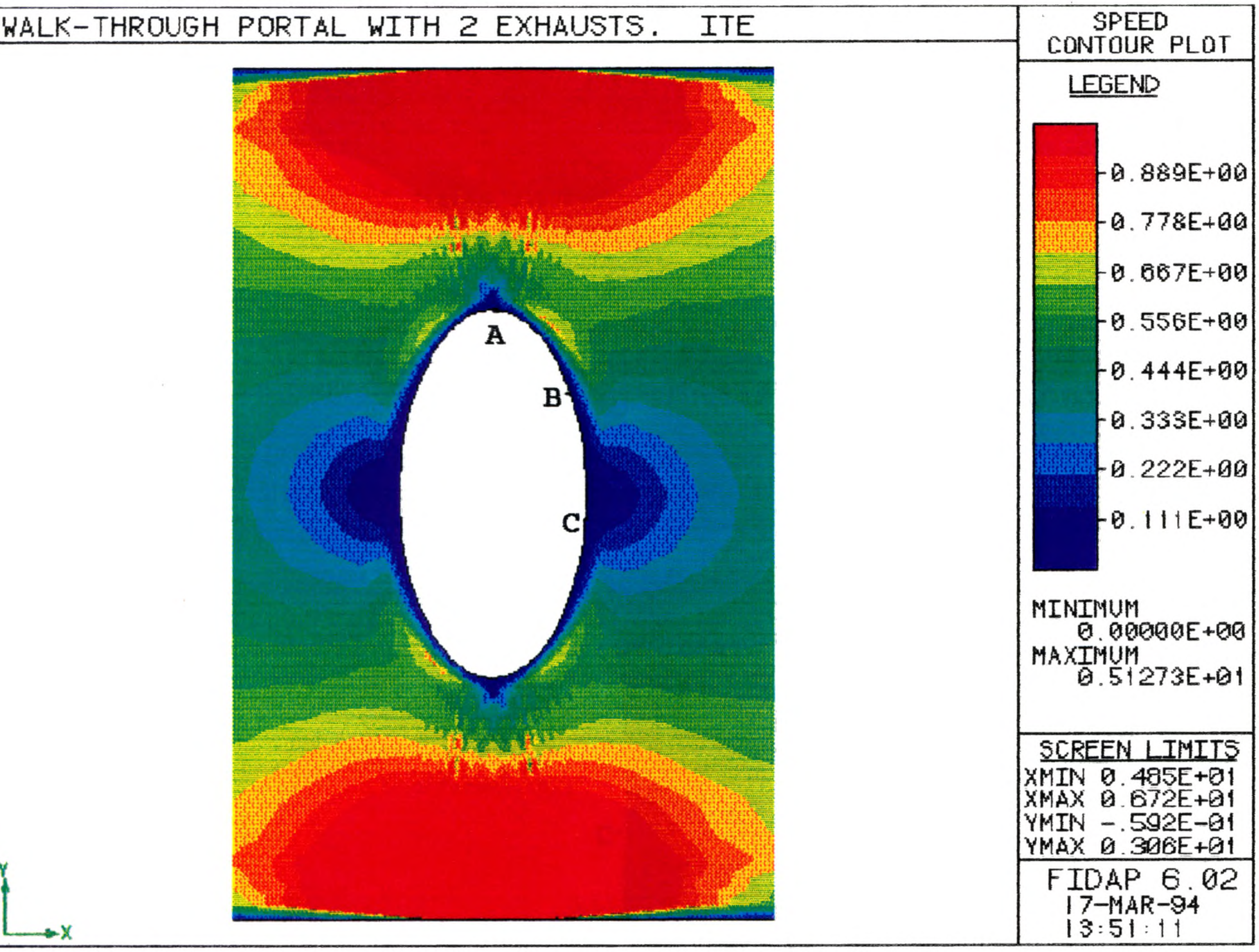

Figure 4: Magnification of the slow-flow layer.

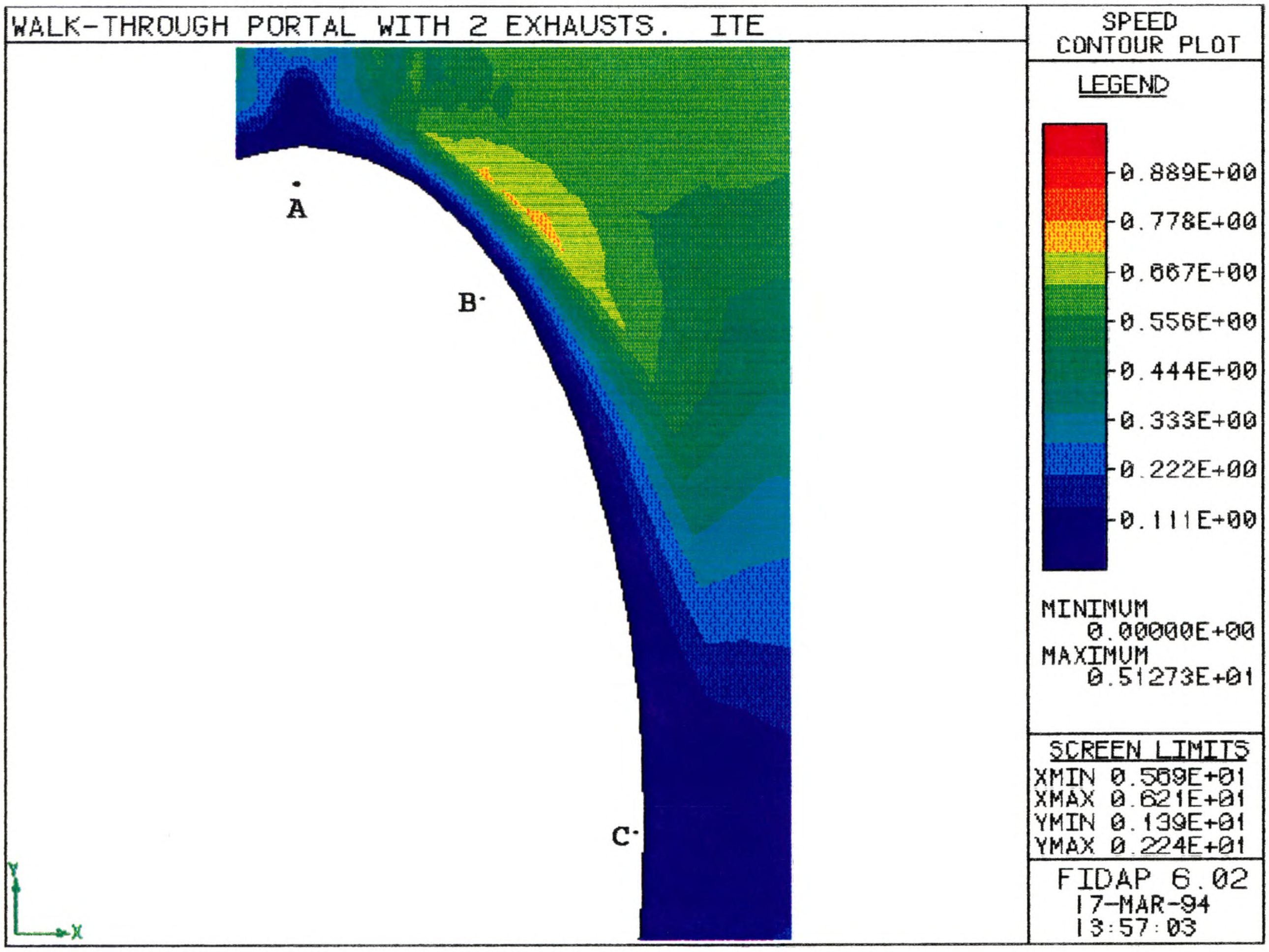

Figure 5: Further magnification of the slow-flow layer.

0.52 feet of the portal. By scaling, the actual thickness of the slow-flow zone at point "A" can now be determined to be 0.78 inch; according to Table 1, RDX would require about 90 seconds to diffuse at this point, far too long for FAA requirements. Similarly, the thickness of the layer at points "B" and "C" can be determined. Therefore, as configured, this portal design is unacceptable.

Figure 6 is a plot of RDX concentration in the portal if a three inch lamina of RDX is placed at the person's side. The concentration of RDX is shown as a mole fraction. The vapor pressure of RDX is such that under steady state conditions 6×10^{-12} mole of RDX is present for every mole of air at the surface of the explosive. At the exit the concentration has decreased substantially. Figure 7 is a plot of the flux of explosives vapor emitted from different locations along the explosive. The units are pounds RDX per square foot per second. The flux varies from 0 at the edges of the block to 0.841×10^{-14} near the mid-point. At steady state, a total of 0.202×10^{-14} pound of RDX is emitted per second.

Figure 8 describes the flow if the bottom funnel is closed off. This change eliminates the large slow-flow zones at the person's front and back, but explosives vapor collection is still inefficient. A large area at the bottom of the plot is now practically devoid of flow, and any explosive hidden at the person's side near this void would probably never be detected. A drastic improvement, however, is accomplished if the original exit at the bottom of the plot is replaced by a blower which supplies air at a speed of 1.0 foot/second (Figure 9). This

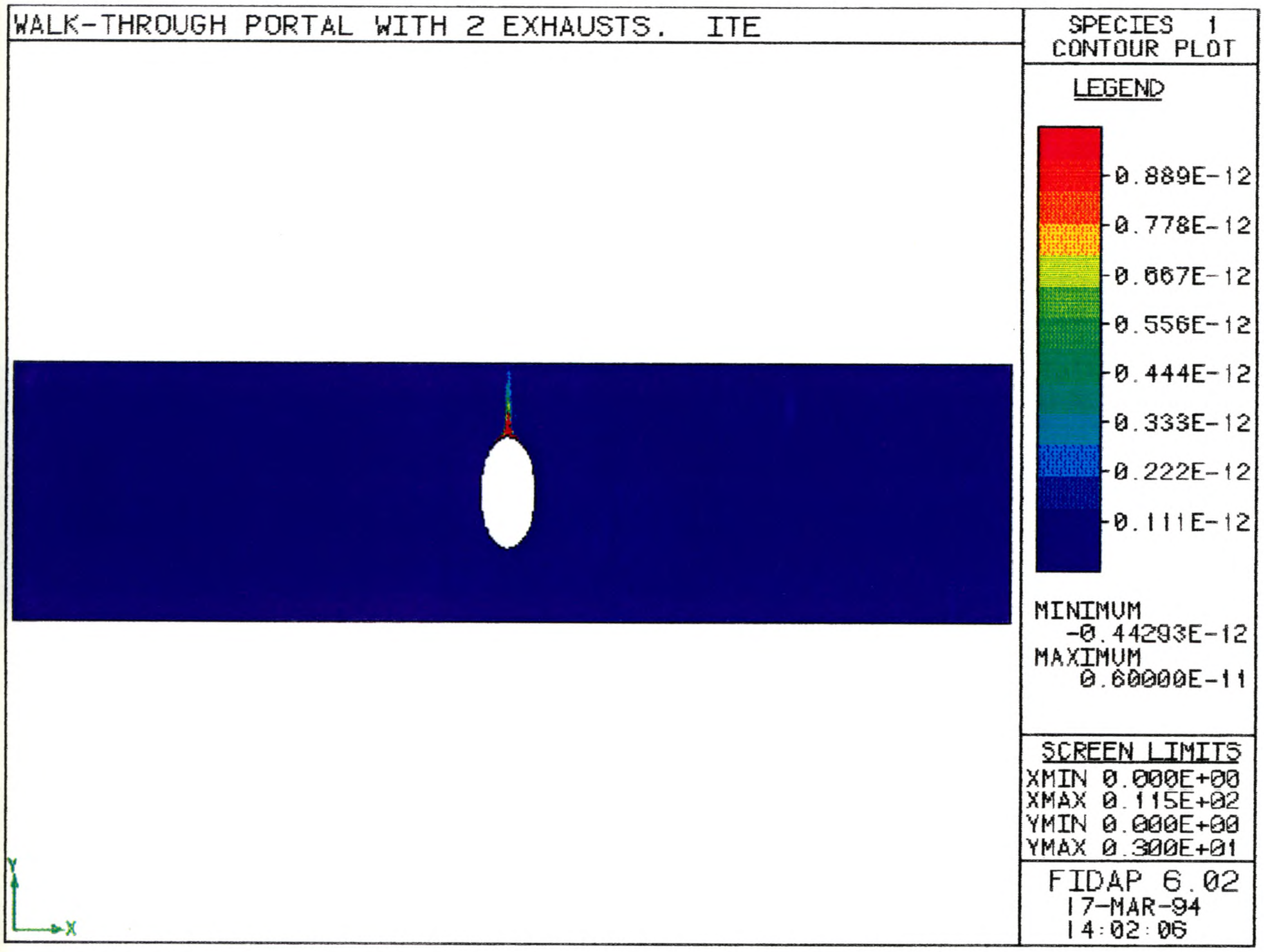

Figure 6: RDX concentration plot.

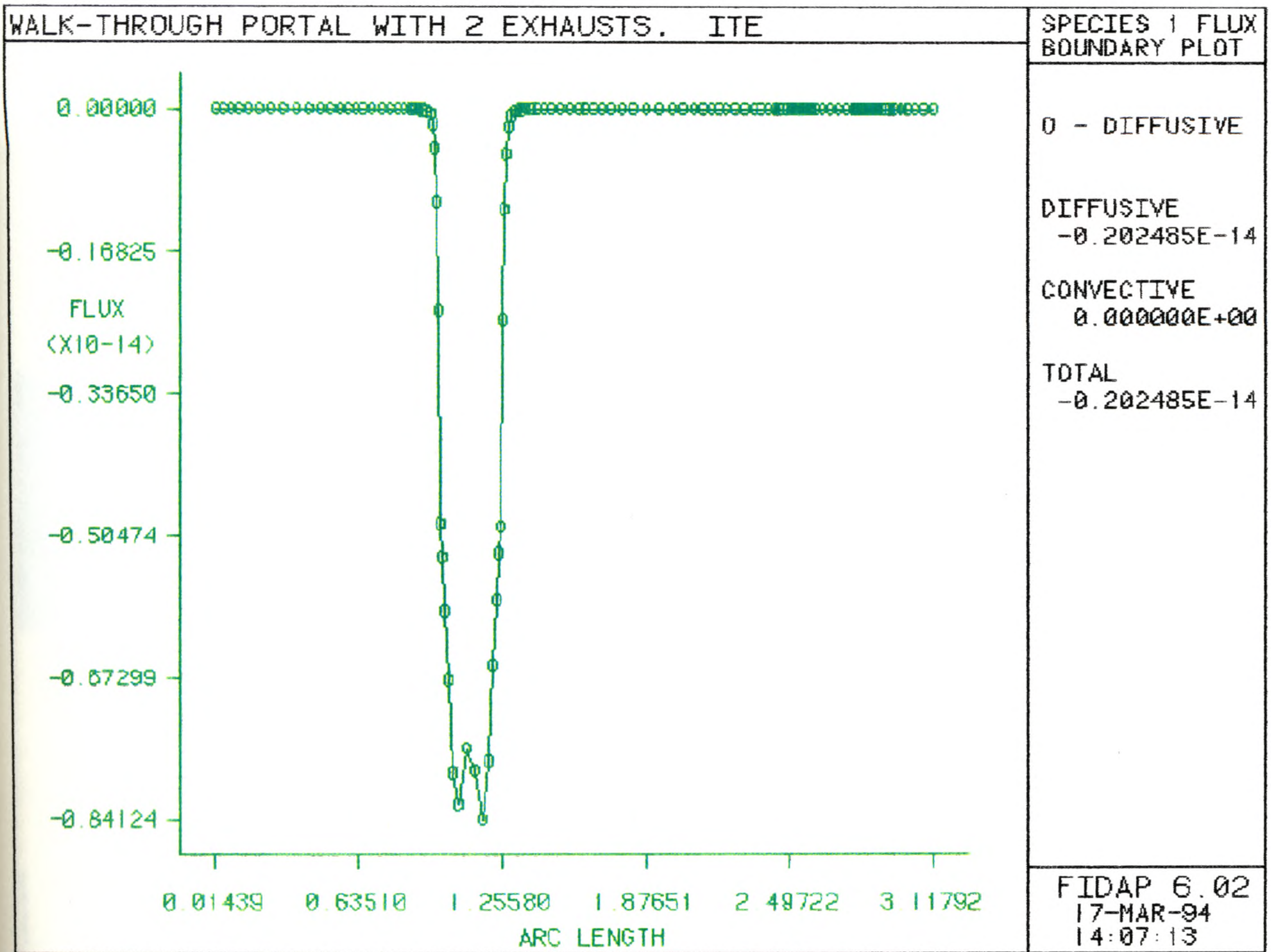

Figure 7: RDX mass flux.

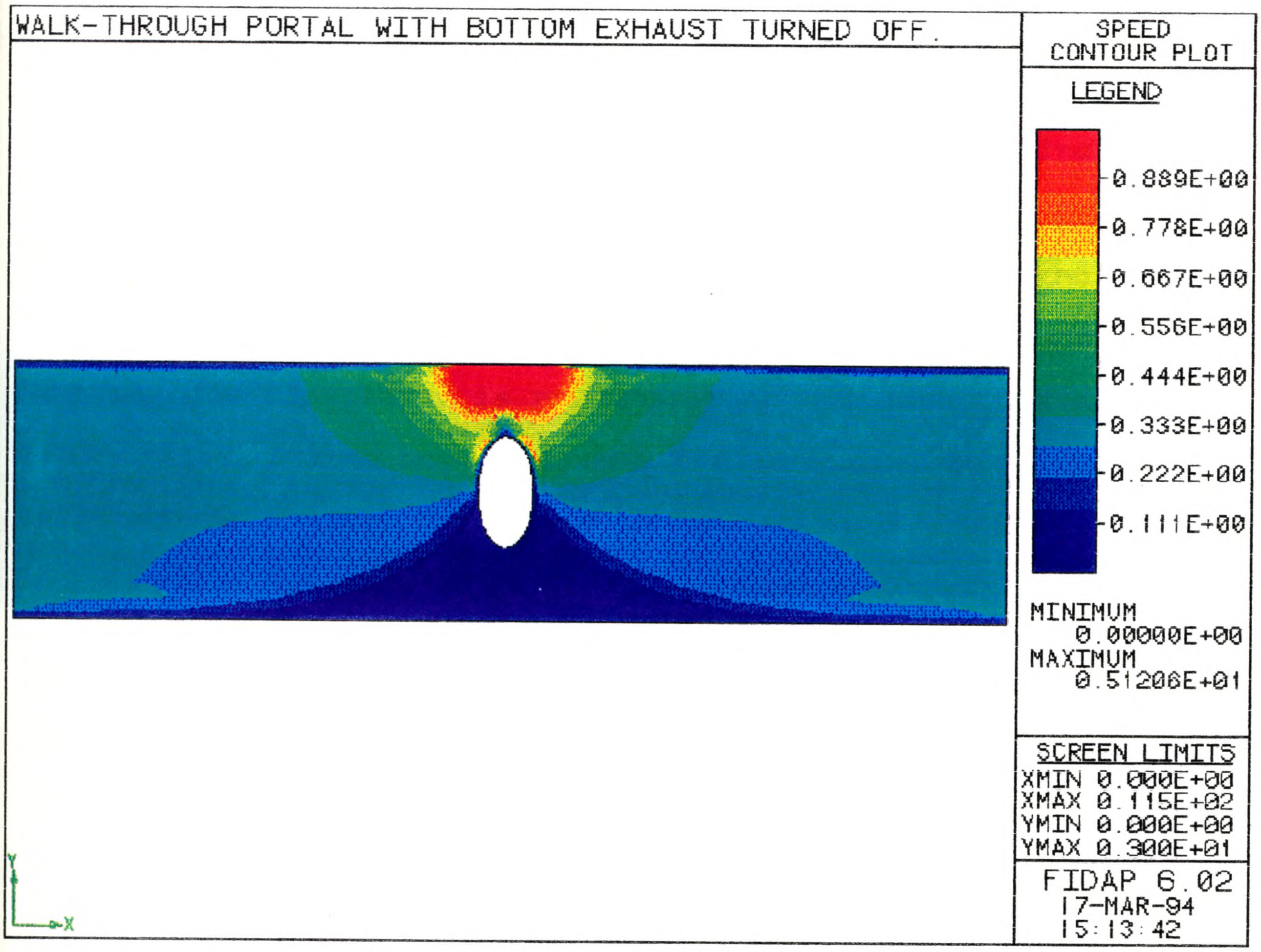

Figure 8: Walk-through portal with no bottom collector.

arrangement eliminates the major slow-flow zones. Figure 10 is a enlargement of the slow-flow layer. Points "A," "B," and "C" illustrate slow-flow layer thickness at three different locations. Figures 11 through 13 further magnify the area around these points. From the Screen Limits, the actual magnitude of the various flow areas can be determined. For example, in Figure 11, since XMIN is 5.43 feet and XMAX is 6.11 feet, the plot depicts 0.68 foot of the portal. By scaling, the actual thickness of the slow-flow zone at point "A" can now be determined to be 0.18 inch; according to Table 1, RDX would require about 5 seconds to diffuse at this point, within FAA requirements. Similarly, the thickness of the layer at points "B" and "C" can be determined using Figures 12 and 13. The entire slow-flow layer is now less than 0.2 inch, and explosives vapor released from any point near the person can be sampled within six seconds.

Figure 14 is a plot of the explosives vapor emitted from different locations along the explosive. The flux varies from 0 at the edges of the block to 0.113×10^{-13} near the mid point. At steady state a total of 0.283×10^{-14} pound of RDX is emitted per second, a 40% improvement over the 0.202×10^{-14} pound per second emitted for the configuration shown in Figure 3.

Figures 15 and 16 are speed plots of an existing walk-in/ walk-out portal, where the person enters and exits through the same opening. The person enters from the left and stops before the exit funnel. A vacuum is applied at the exit, causing air to flow from left to right, sweeping around the person and exiting through the

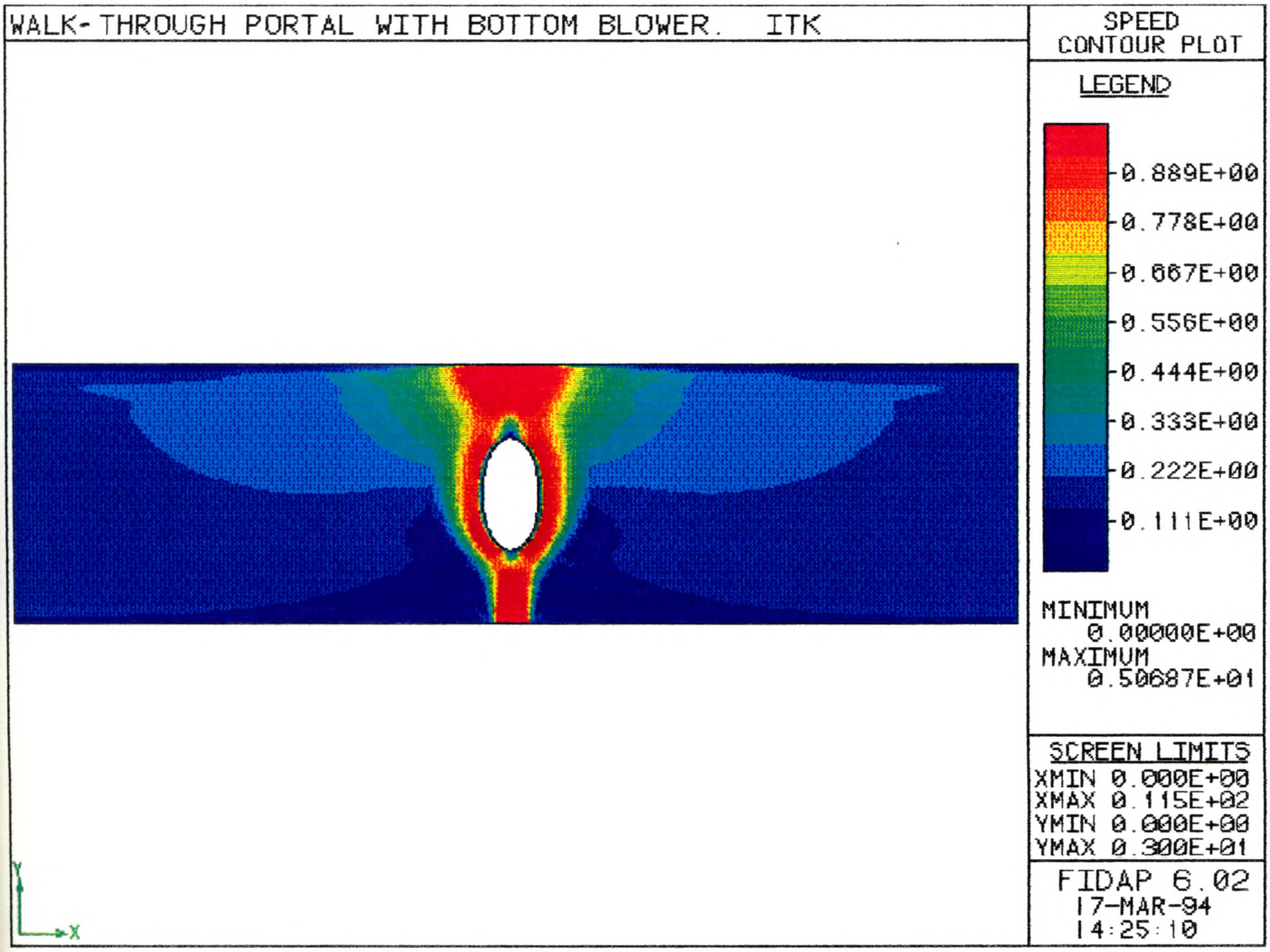

Figure 9: Walk-through portal with bottom blower.

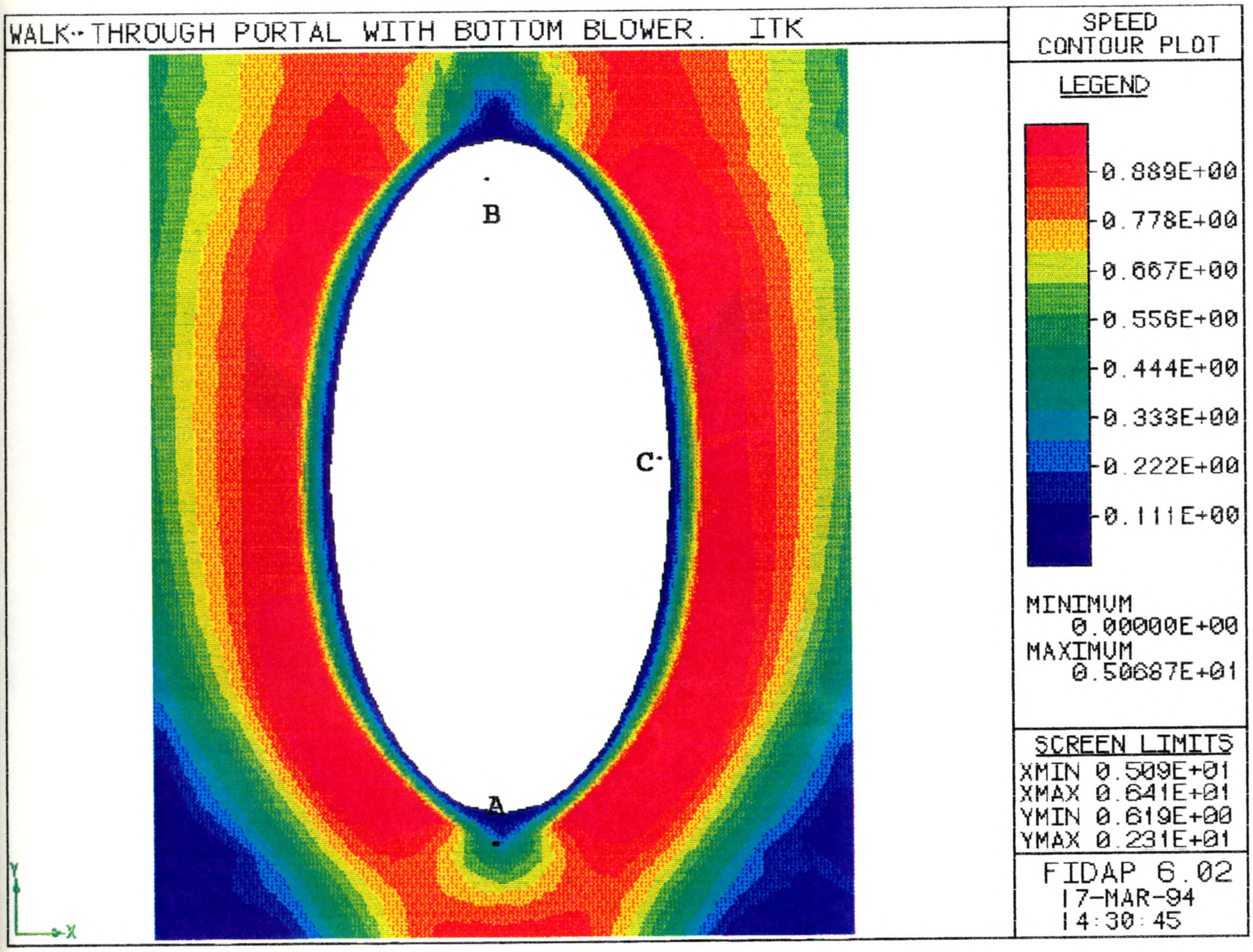

Figure 10: Magnification of the slow-flow layer.

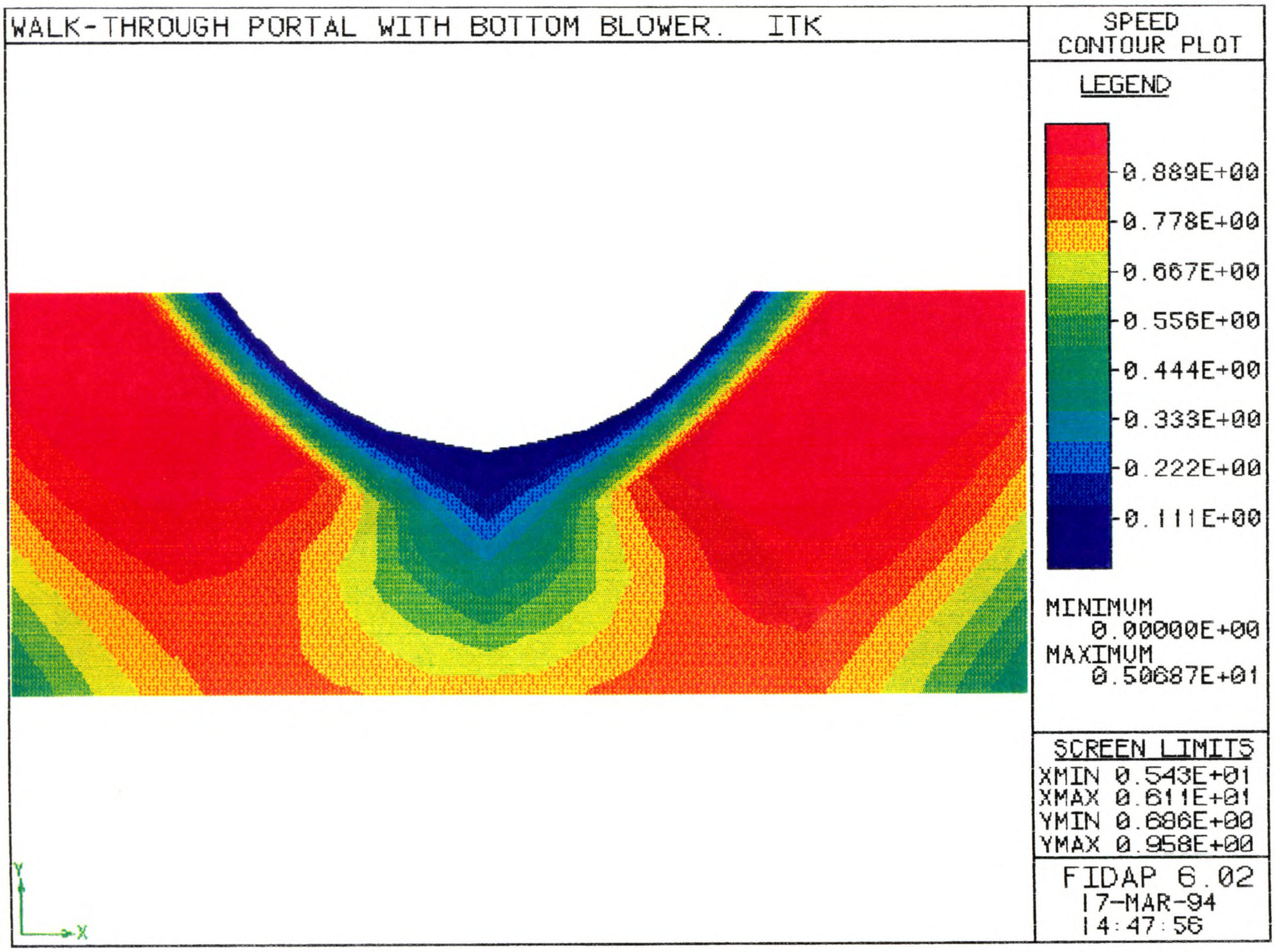

Figure 11: Magnification of the slow-flow layer adjacent to the stagnation point.

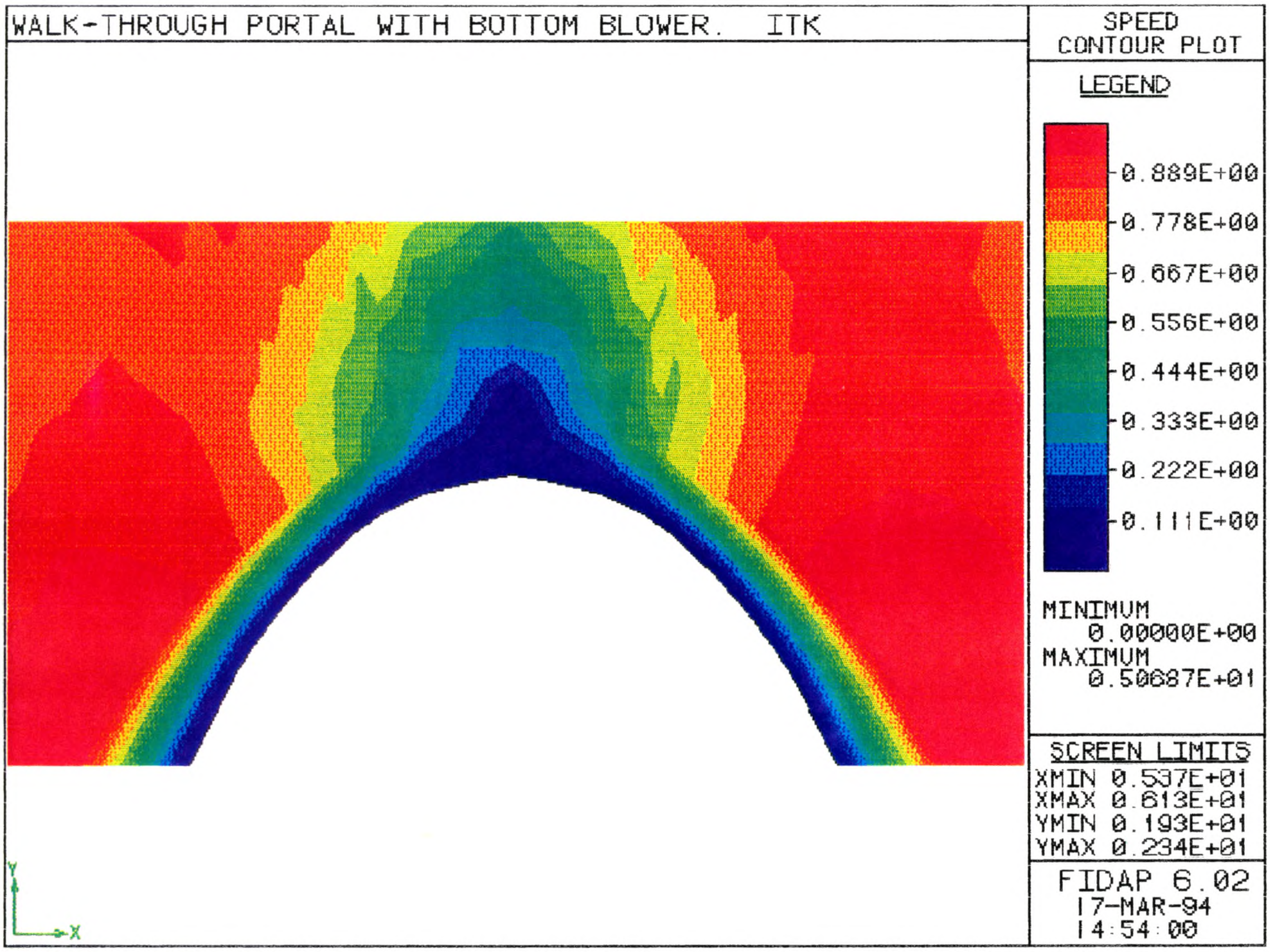

Figure 12: Magnification of the wake.

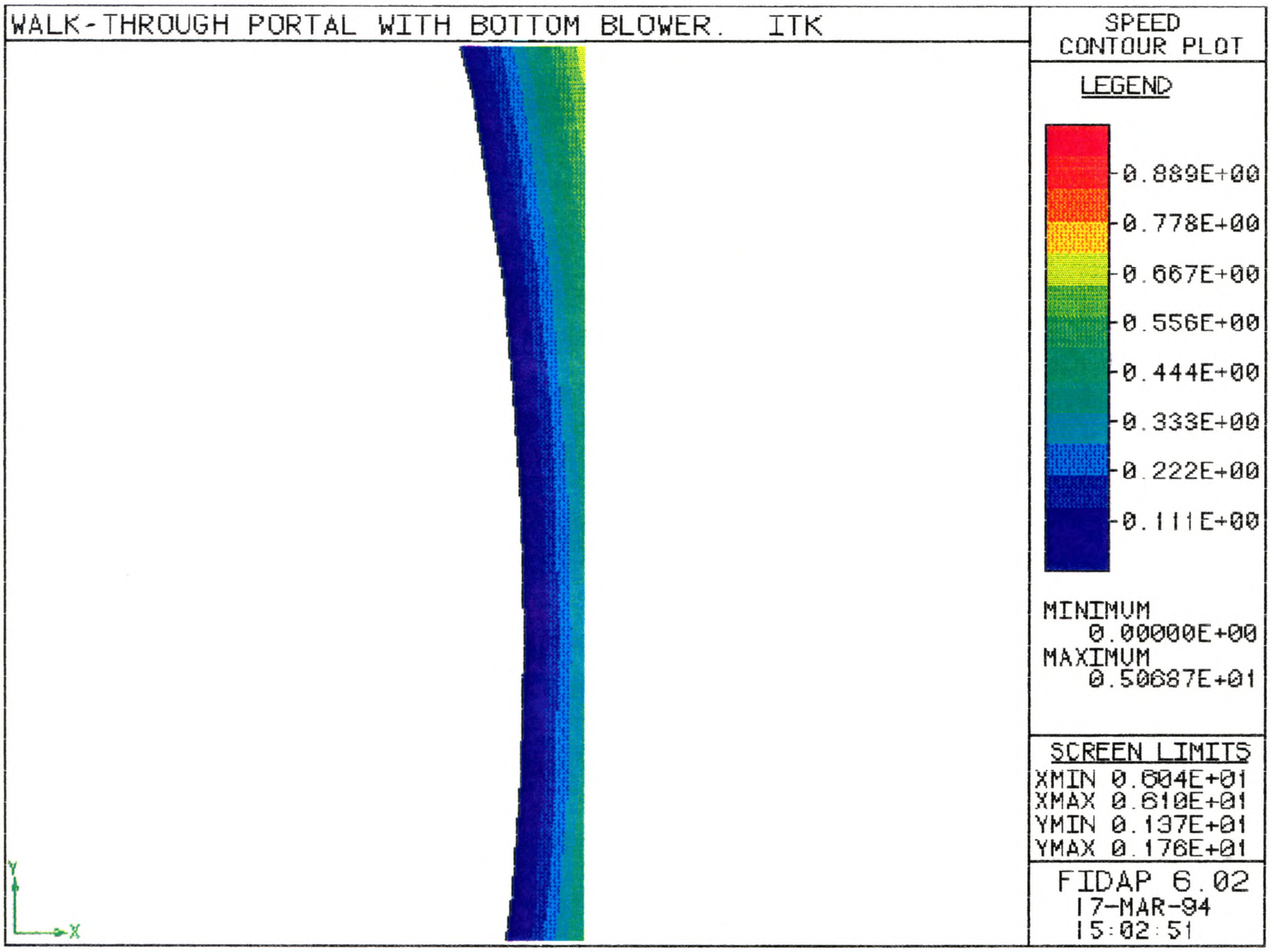

Figure 13: Magnification of the slow-flow zone at the person's front

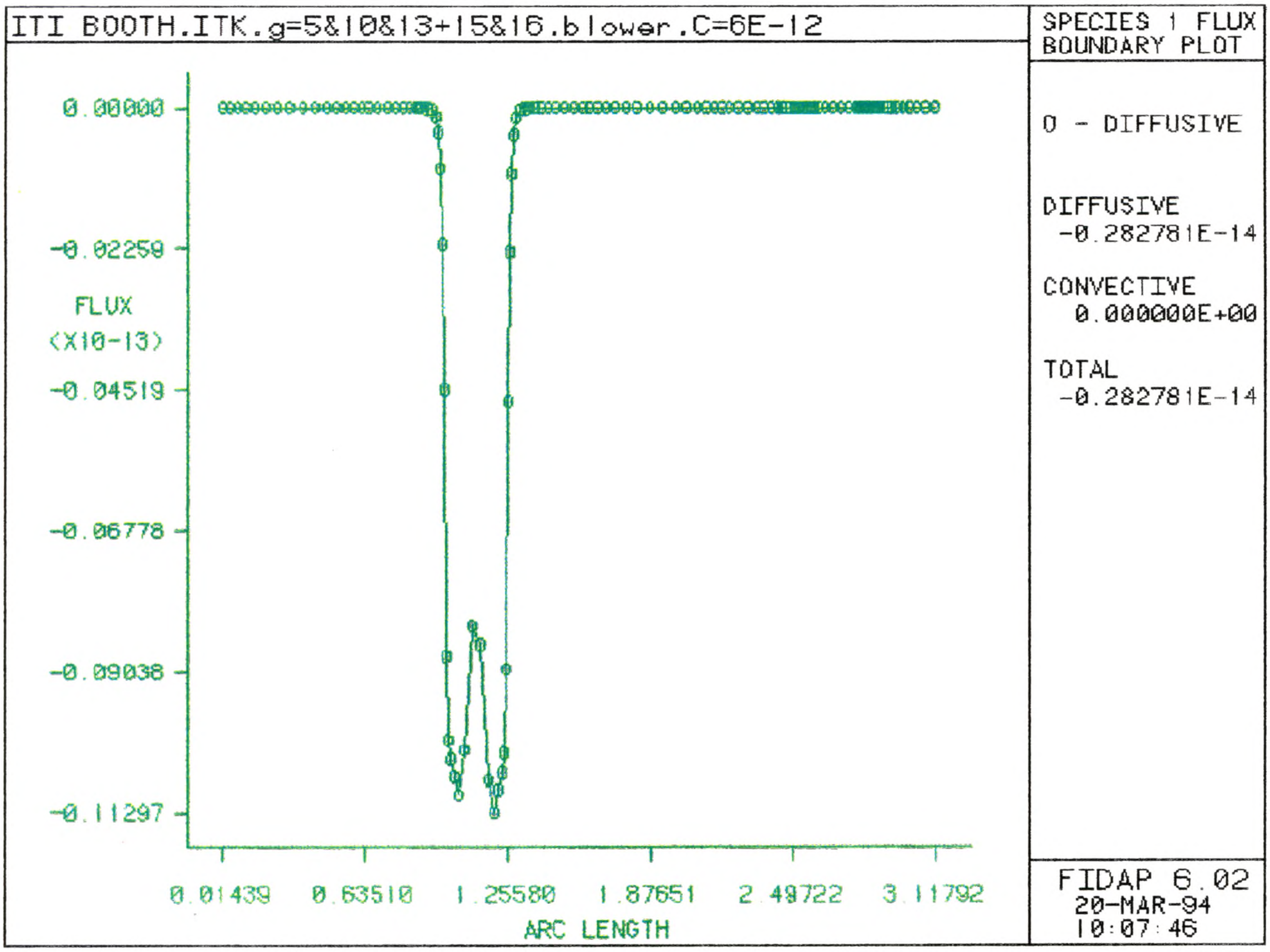

Figure 14: RDX mass flux.

funnel. The two problem areas, once again, are the stagnation point at the person's back, and the large swirling wake in front. Since the person is turned perpendicular to the flow, the area of the wake is much larger than it would be if the person were turned 90 degrees. In Figure 16 the area around the person is enlarged in order to better view the slow-flow layer, which is thin at the person's sides (point B) but broadens at the person's front and back. From the Screen Limits, the actual magnitude of the various flow areas can be determined. For example, since XMIN is 2.01 feet and XMAX is 3.70 feet, the plot depicts 1.69 feet of the portal. By scaling, the actual thickness of the slow-flow zone at point "A" can now be determined to be 0.52 inch; according to Table 1, RDX would require about 40 seconds to diffuse at this point, far too long for FAA requirements. Similarly, the thickness of the layer at points "B" and "C" can be determined. As configured, this portal design is unacceptable. To be fair, this design employed intermittent puffers to break up the wake, but a design which produces a small wake seems preferable.

Figure 17 depicts a design suggested by William Curby of the FAA Technical Center. This portal uses the same exit funnel, exit conduit, and exit flow rate as the previous portal, and thus becomes a walk-through portal. The person is turned 90 degrees in order to present a slimmer profile to the flow. The blower at the left of the Figure introduces air at a speed of 1.5 feet per second, creating a cross flow past the person toward the exit at the right. Since the booth's entrance and exit (top and bottom of

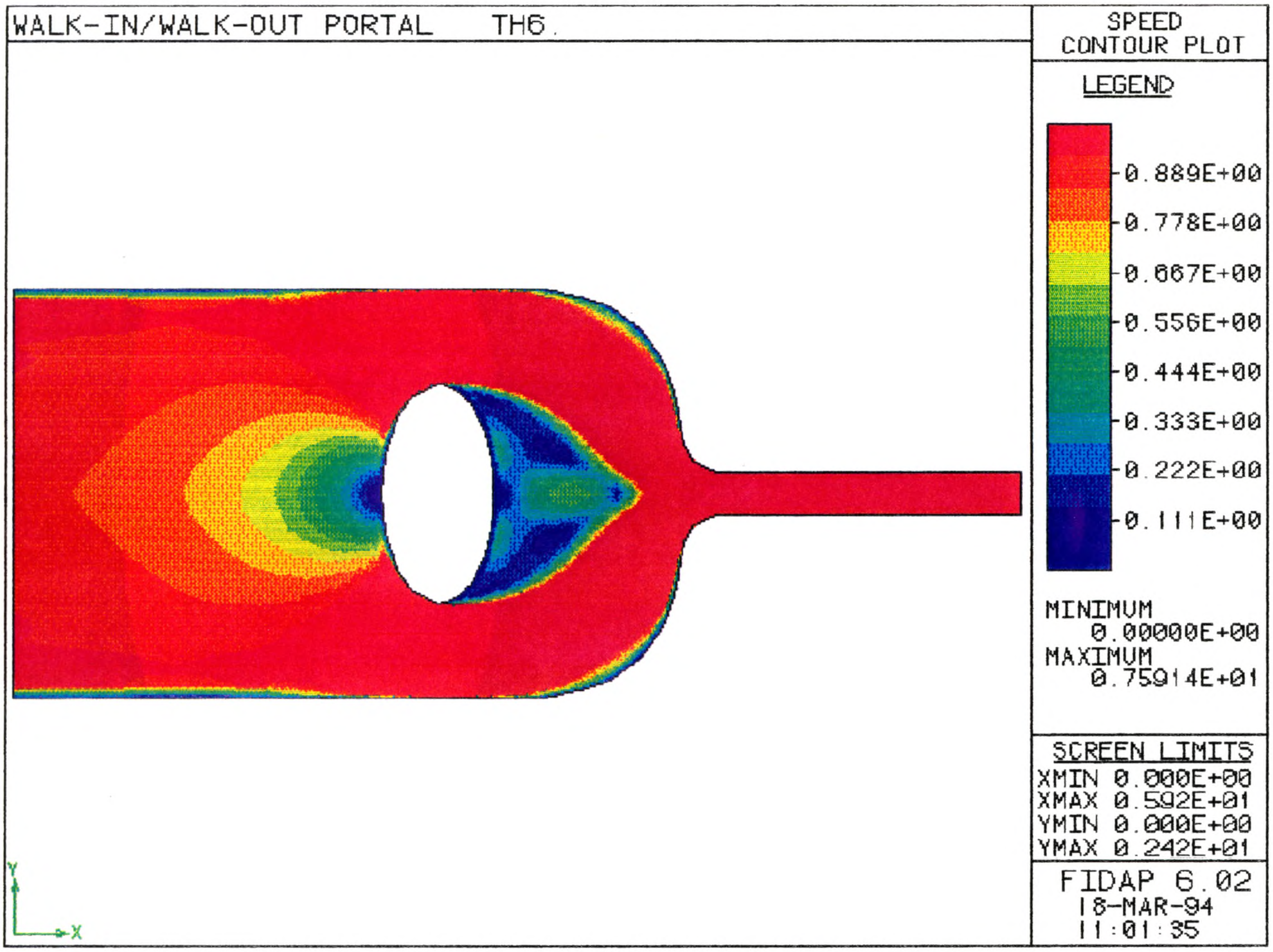

Figure 15: Contour speed plot. Walk-in/ walk-out portal.

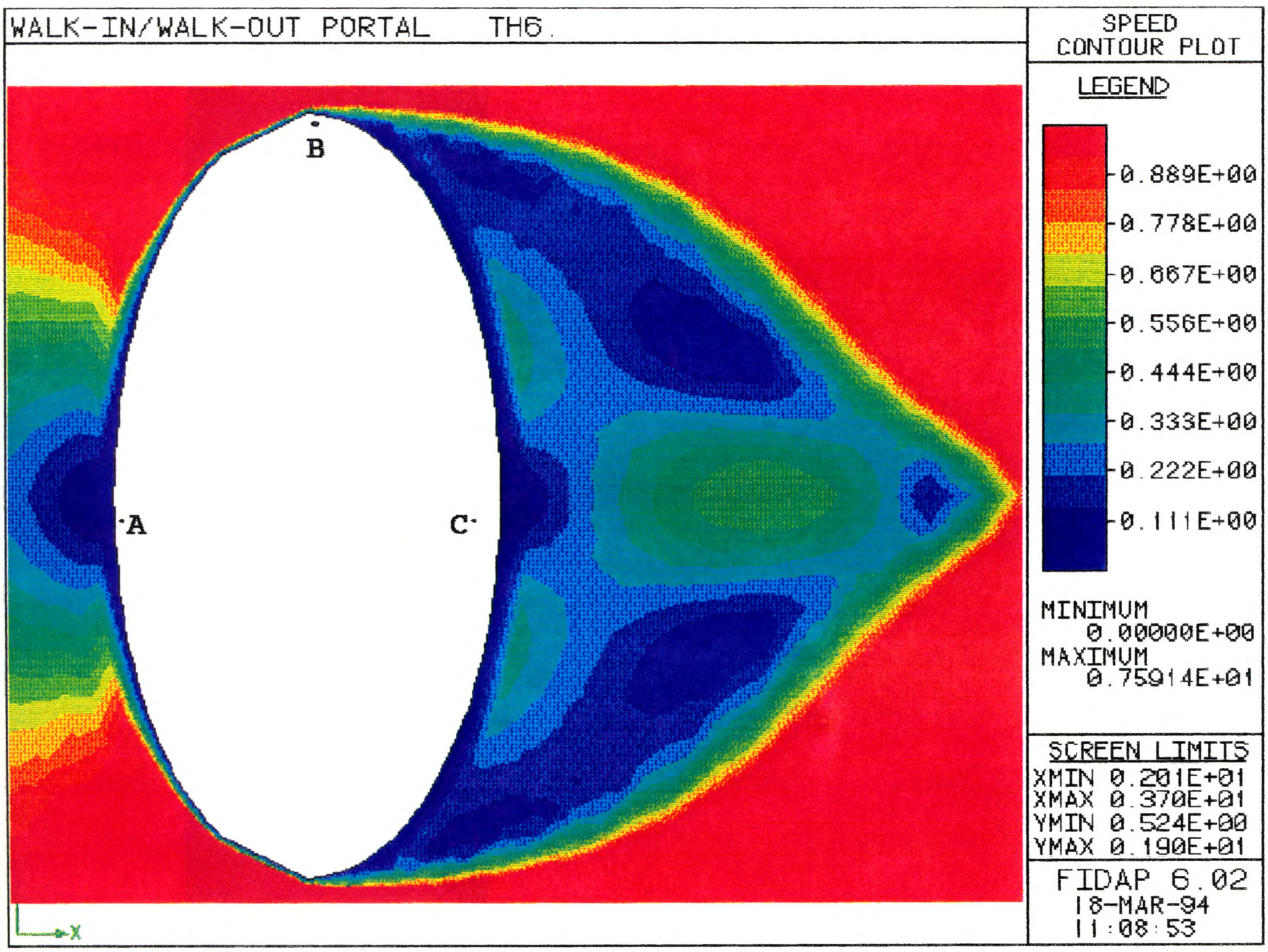

Figure 16: Magnification of the slow-flow zone.

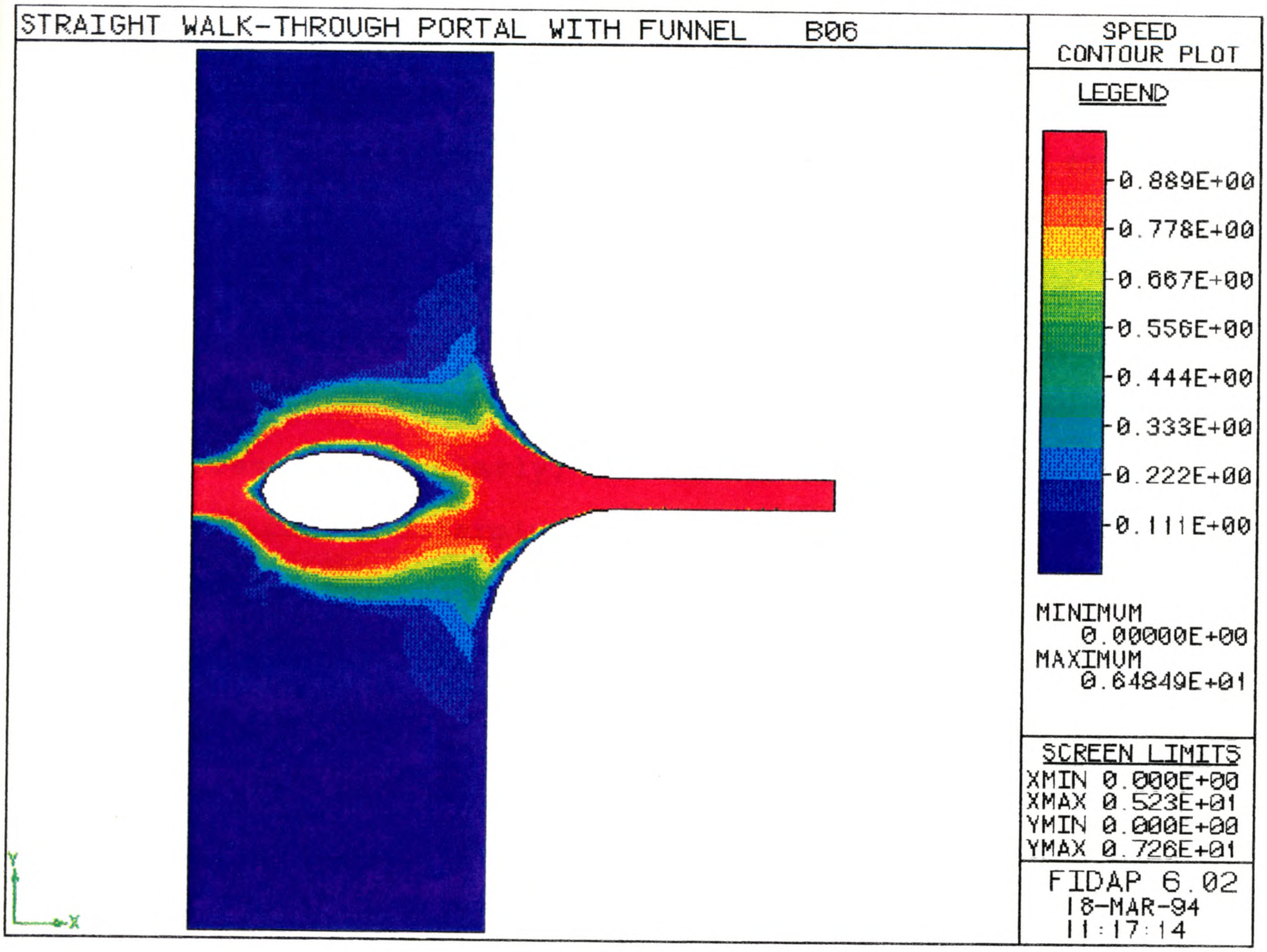

Figure 17: Speed plot of a walk-through portal.

the Figure) are open to the atmosphere, air flows from these openings to the funnel as well. The size of the slow-flow layer at the stagnation point and at the wake have been greatly reduced. In Figure 18 the area around the person is enlarged in order to better view the slow-flow layer. Figures 19-21 are further magnifications of the slow-flow layer. Points "A," "B," and "C" illustrate slow-flow layer thickness at three different locations. From the Screen Limits, the actual magnitude of the various flow areas can be determined. For example, in Figure 19, since YMIN is 3.42 feet and YMAX is 3.86 feet, the plot depicts 0.44 feet of the portal. By scaling, the actual thickness of the slow-flow zone at point "A" can now be determined to be 0.19 inch; according to Table 1, RDX would require about 6 seconds to diffuse at this point, close to FAA requirements. Similarly, the thickness of the layer at points "B" and "C" can be determined using Figures 20 and 21. Therefore, as configured, this portal is now acceptable.

Figure 22 is a plot of RDX concentration in the portal, if a six inch lamina of RDX is placed at the person's back. Figure 23 is a plot of the flux of explosives vapor emitted from different locations along the explosive. The flux varies from 0 at the edges of the explosive to 0.143×10^{-13} near the mid point. At steady state, a total of 0.748×10^{-14} pounds of RDX are emitted per second.

Figure 24 shows another design suggested by William Curby. The part of the portal near the blower is now shaped to match the curvature of the exit funnel. The net effects are to force the person to pass nearer the exit, and to facilitate the flow from the

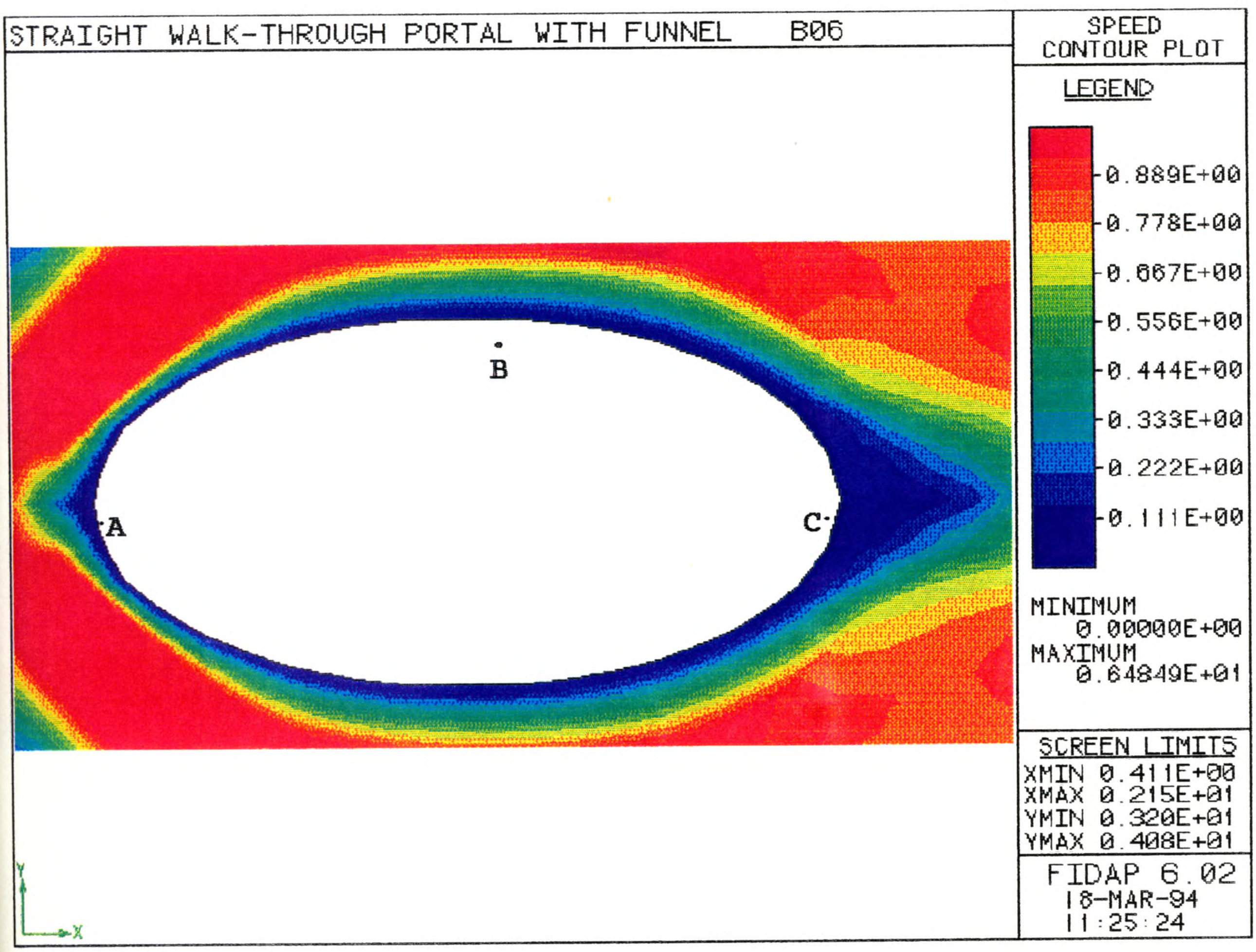

Figure 18: Magnification of the slow-flow layer.

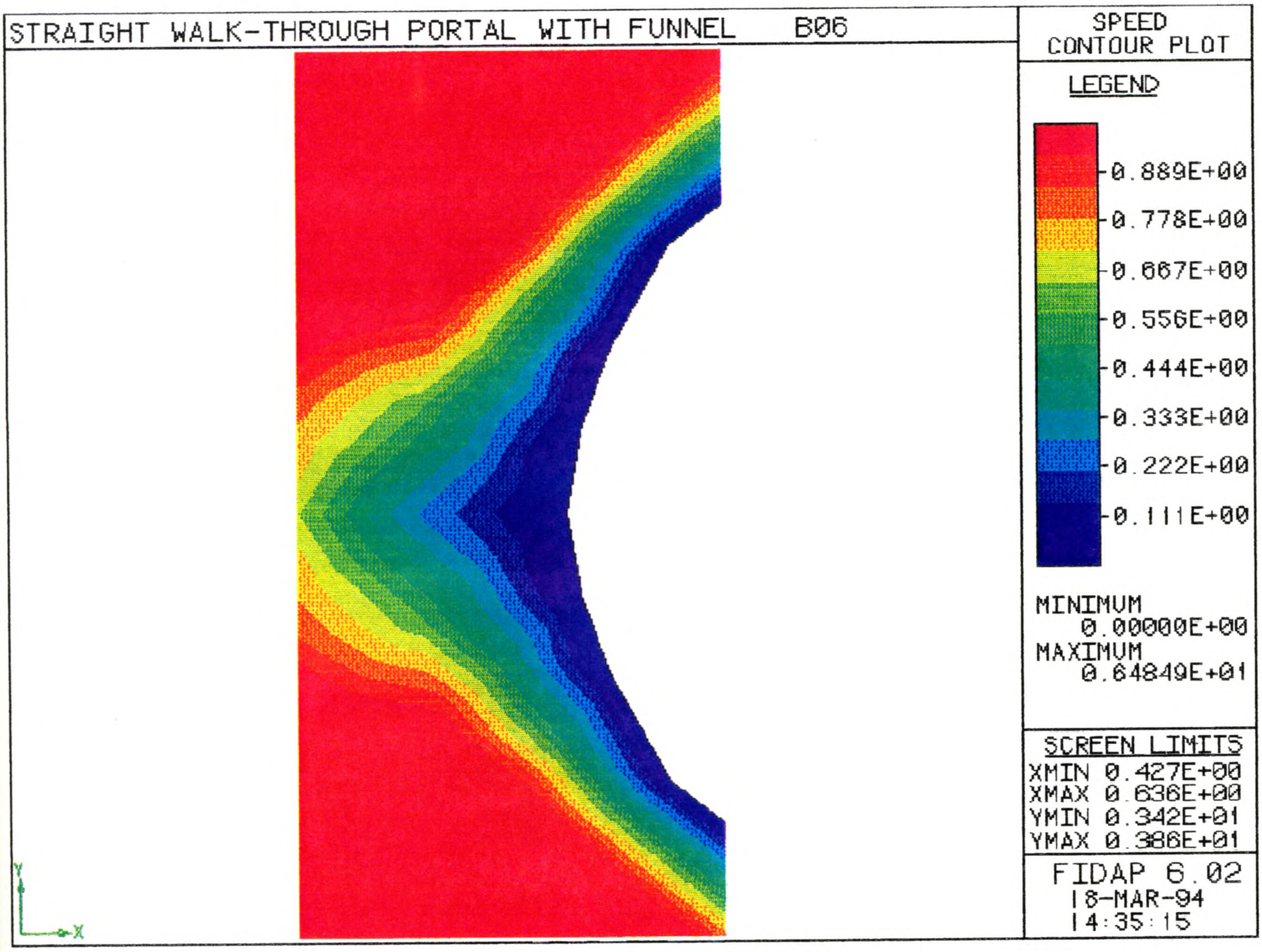

Figure 19: Magnification of the slow-flow layer adjacent to the stagnation point.

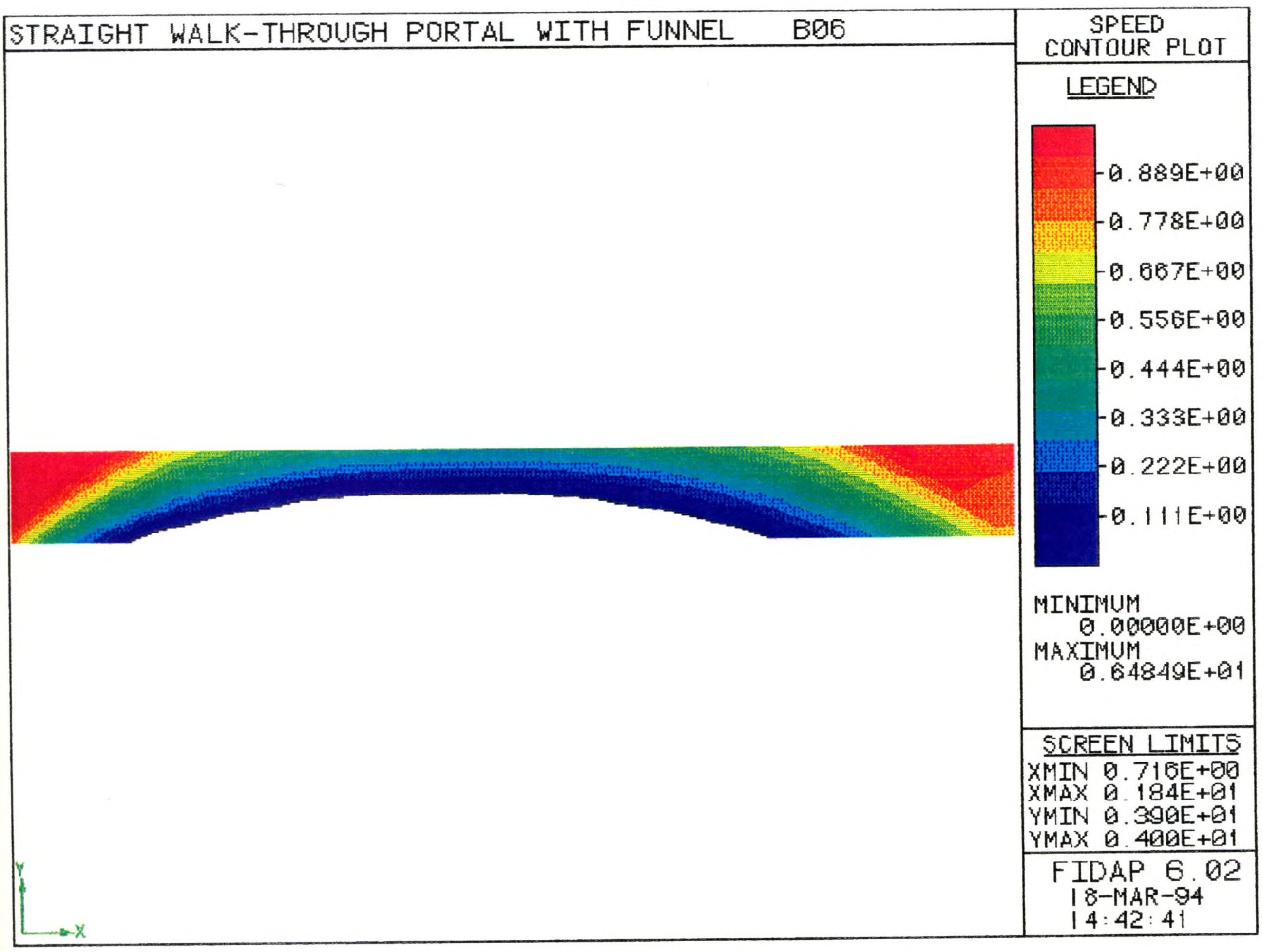

Figure 20: Magnification of the slow-flow layer at the person's back.

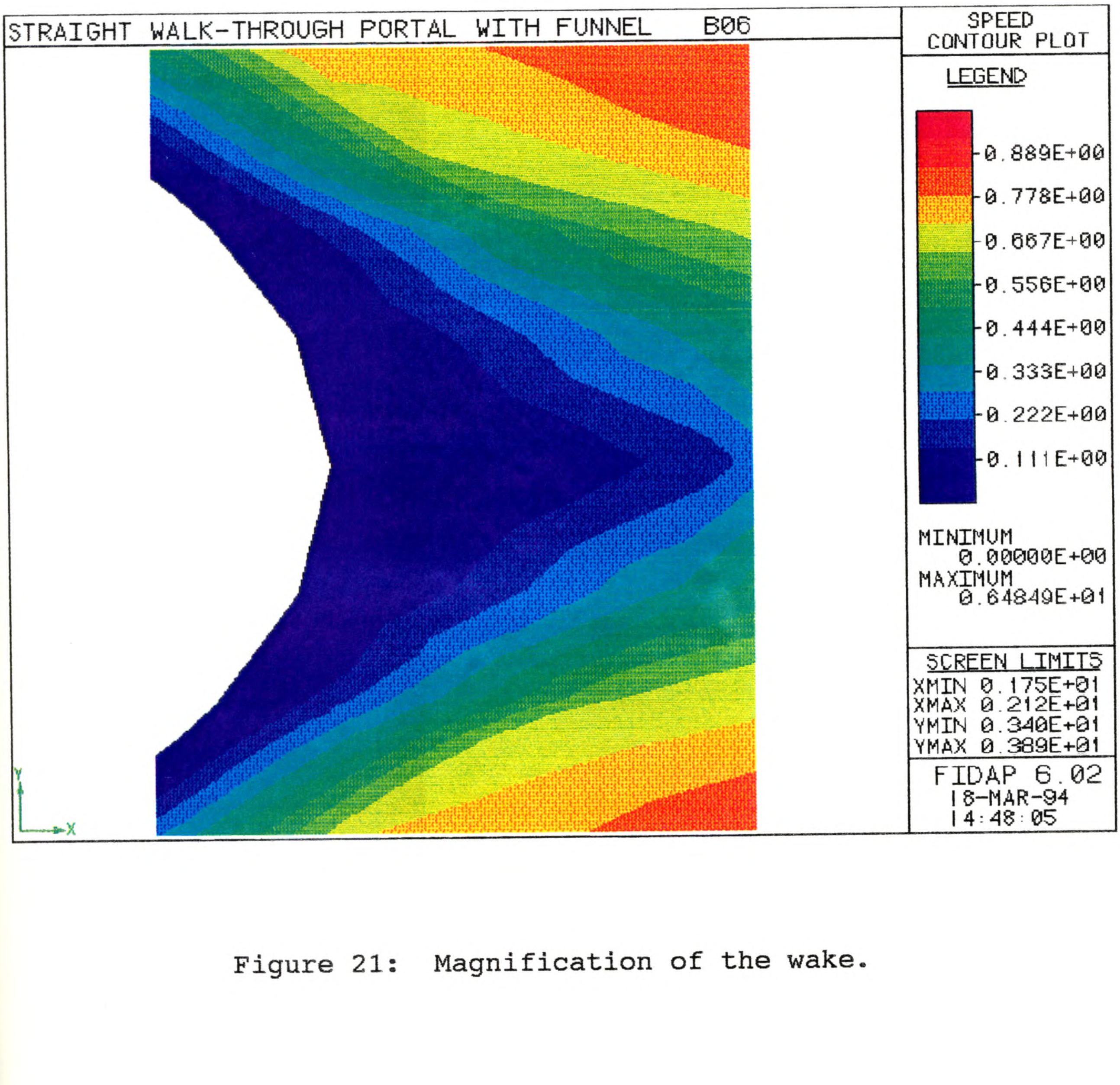

Figure 21: Magnification of the wake.

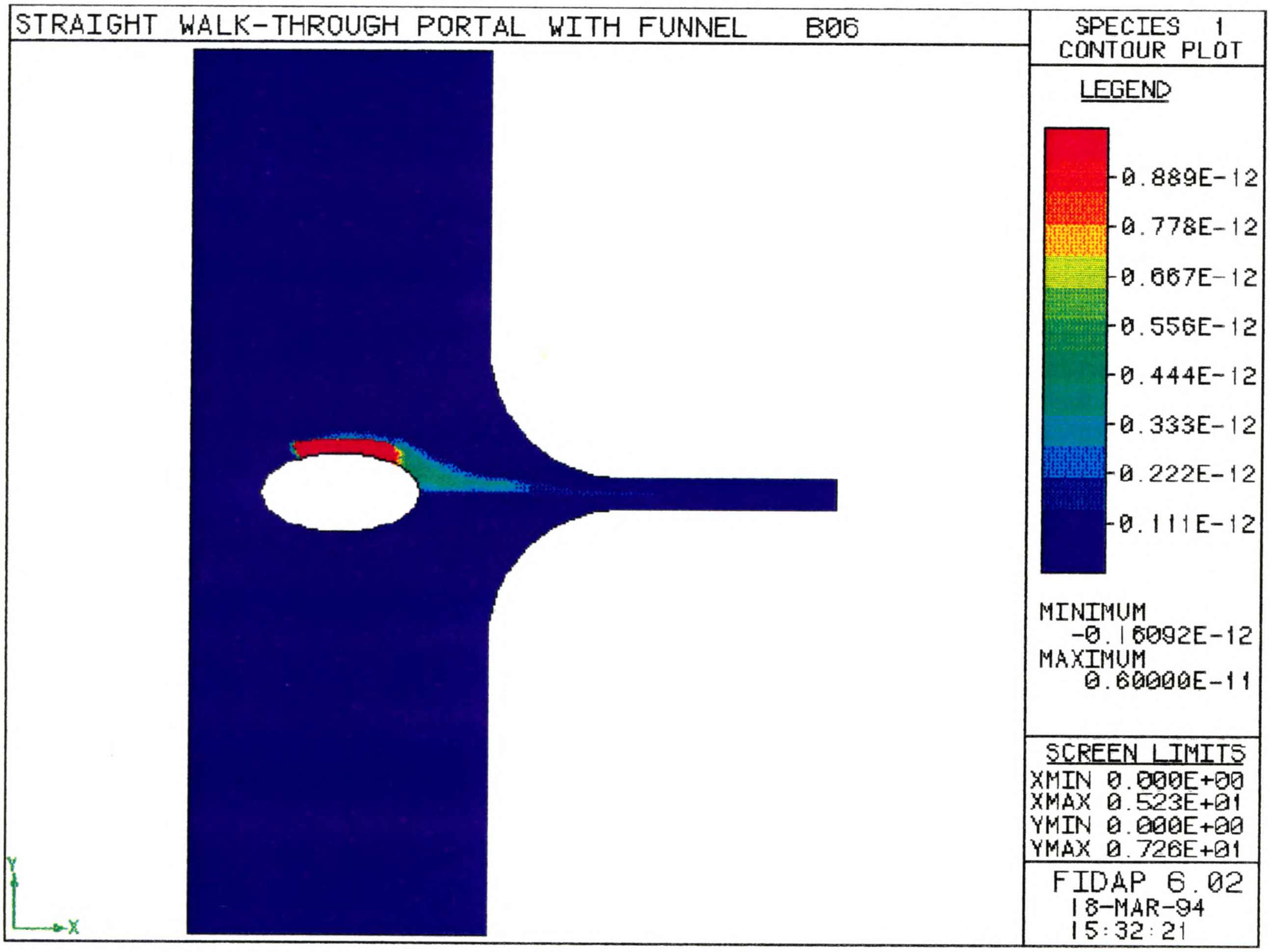

Figure 22: RDX concentration plot.

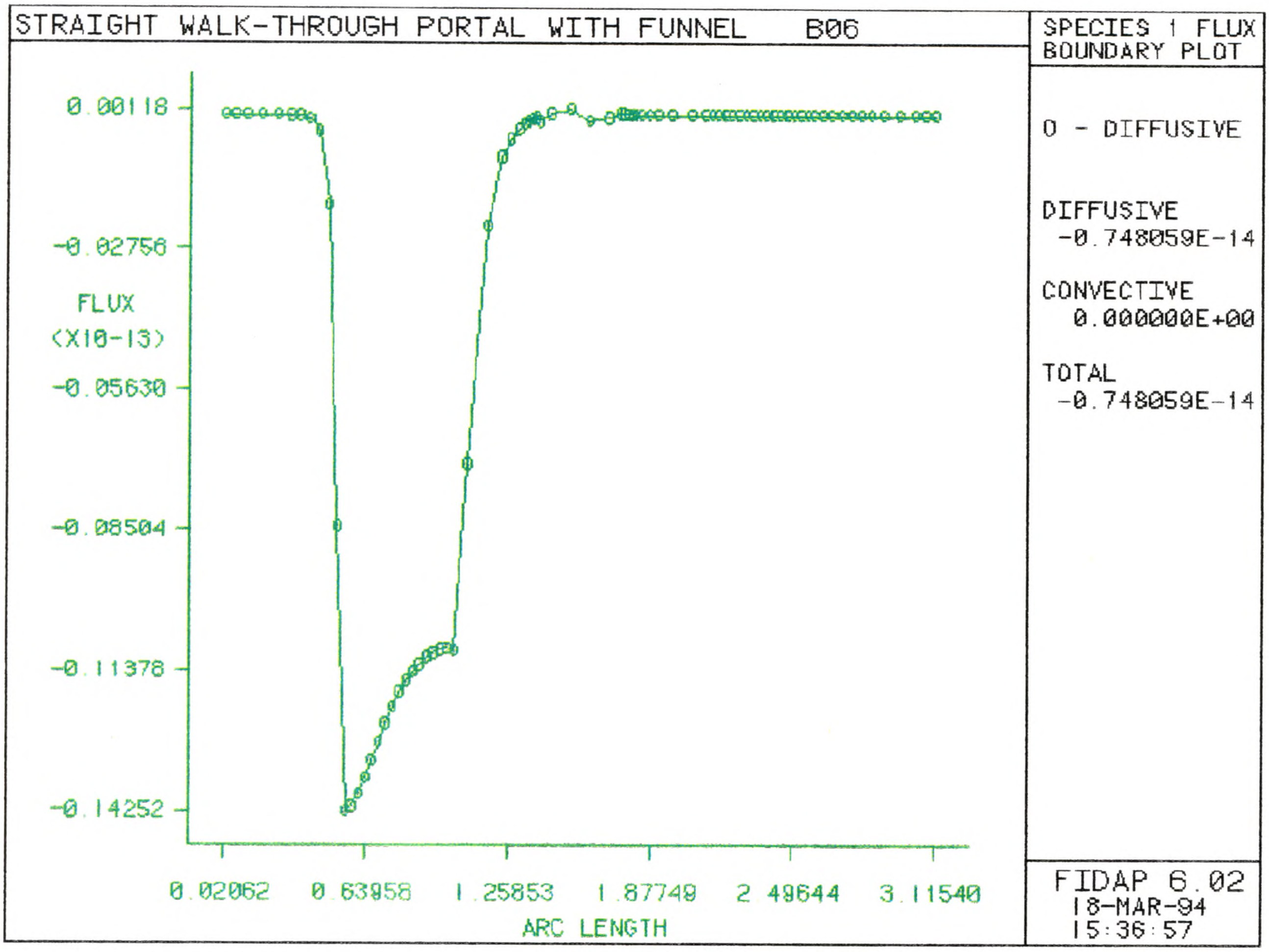

Figure 23: RDX flux plot.

ends of the portal towards the exit. By moving the person nearer to the exit, RDX vapor would start nearer the exit, reducing transit time. In Figure 25, the area around the person is enlarged in order to better view the slow-flow layer. Figures 26-28 are further magnifications of the slow-flow layer. Points "A," "B," and "C" are to illustrate slow-flow layer thickness at three different locations. From the Screen Limits, the actual magnitude of the various flow areas can be determined. For example, in Figure 26, since YMIN is 3.39 feet and YMAX is 3.84 feet, the plot depicts 0.45 feet of the portal. By scaling, the actual thickness of the slow-flow zone at point "A" can now be determined to be 0.18 inch; according to Table 1, RDX would require about 6 seconds to diffuse at this point, close to FAA requirements. Similarly, the thickness of the layer at points "B" and "C" can be determined using Figures 27 and 28.

Figure 29 is a plot of RDX concentration in the portal if a six inch lamina of RDX is placed at the person's back. Figure 30 is a plot of the flux of explosives vapor emitted from different locations along the explosive. The flux varies from 0 at the edges of the explosive to 0.177×10^{-13} near the midpoint. At steady state, a total of 0.858×10^{-14} pound of RDX is emitted per second. The effects of curving the portal, therefore, were a marginal reduction of the slow-flow layer and a slightly larger mass flux of explosives vapor.

Figures 31-46 present portals which have no cross flow. These configurations were suggested by Daniel Lucero of Lucero Labs,

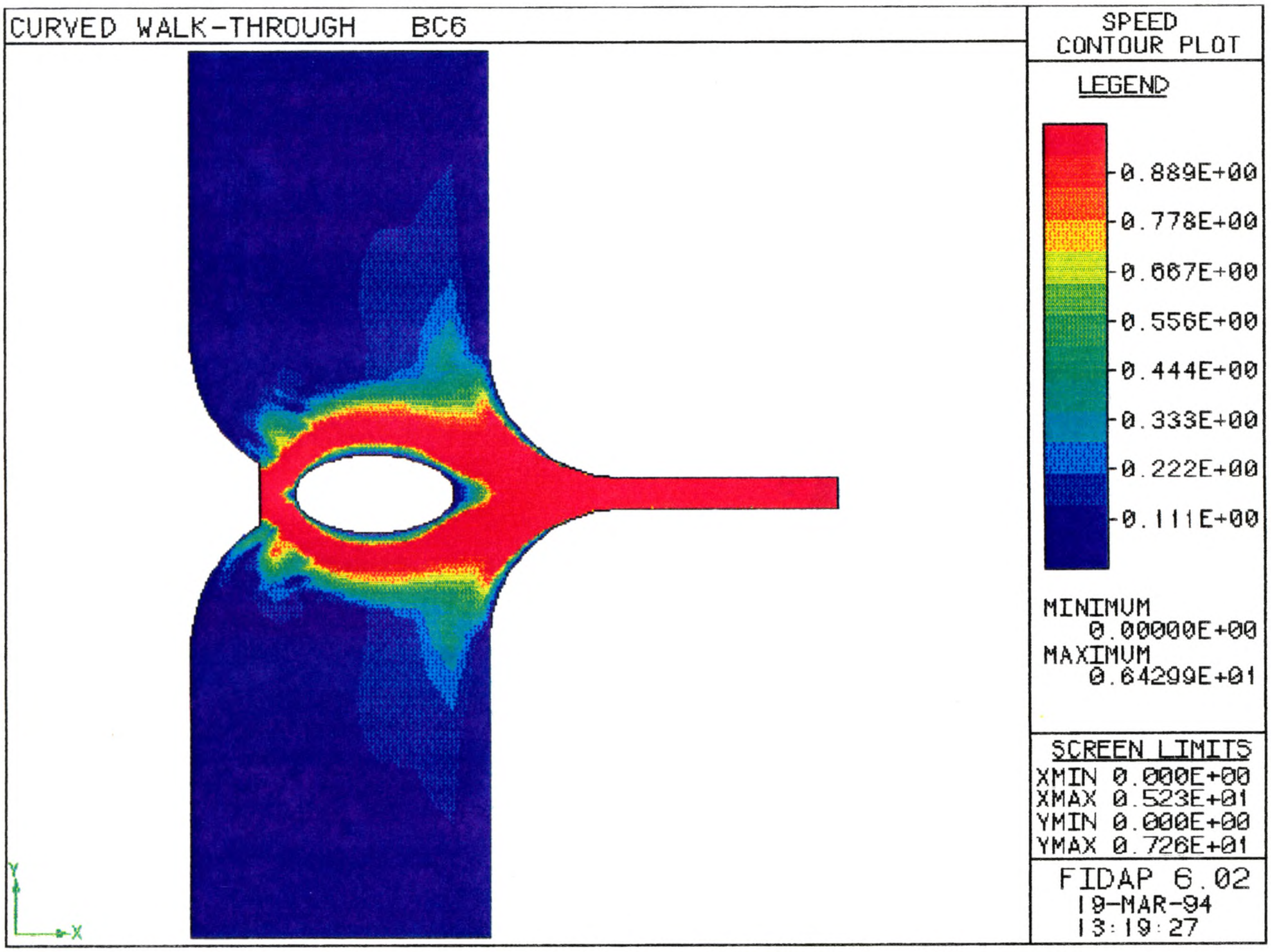

Figure 24: Speed plot of curved walk-through portal.

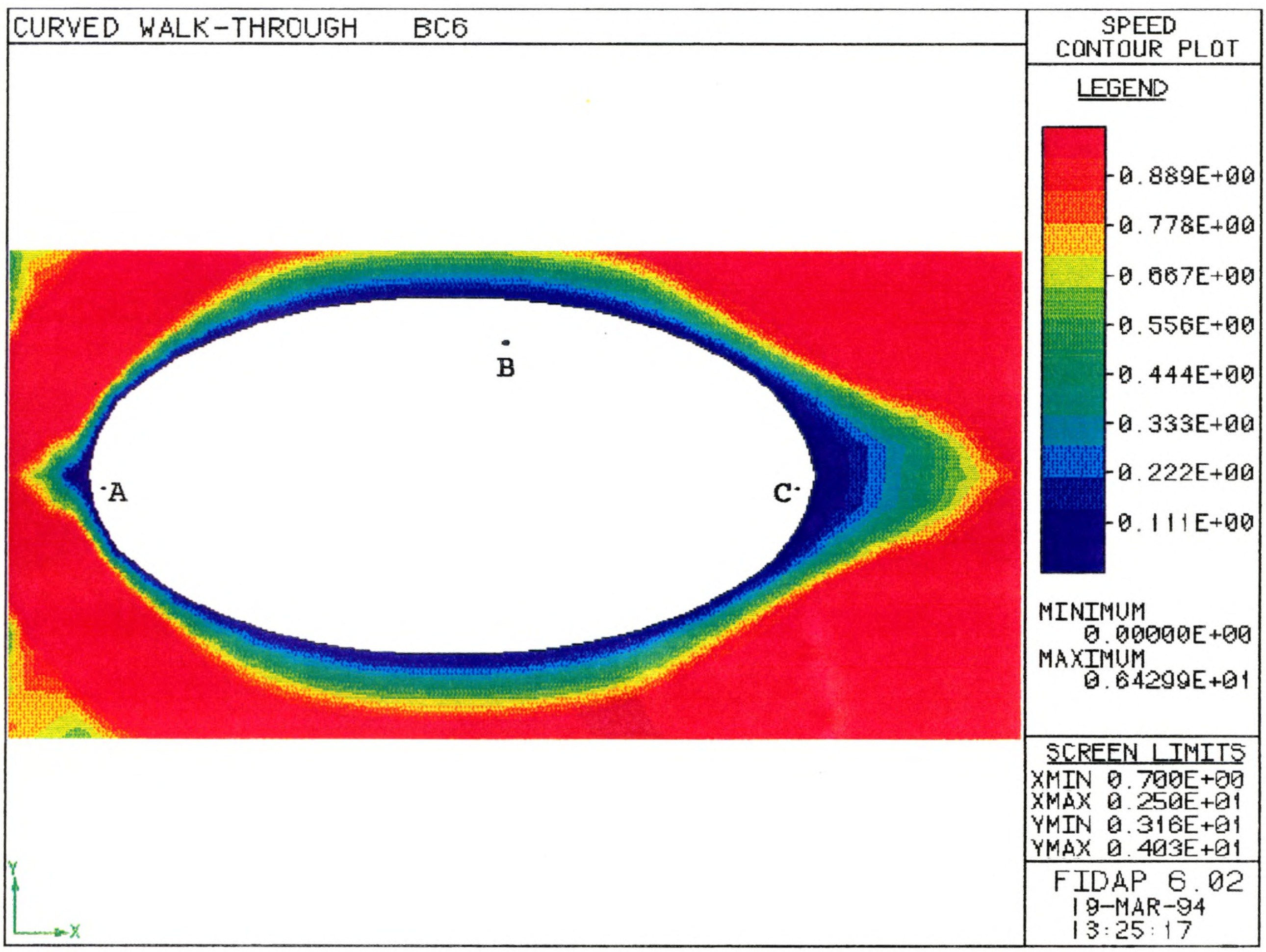

Figure 25: Magnification of the slow-flow layer.

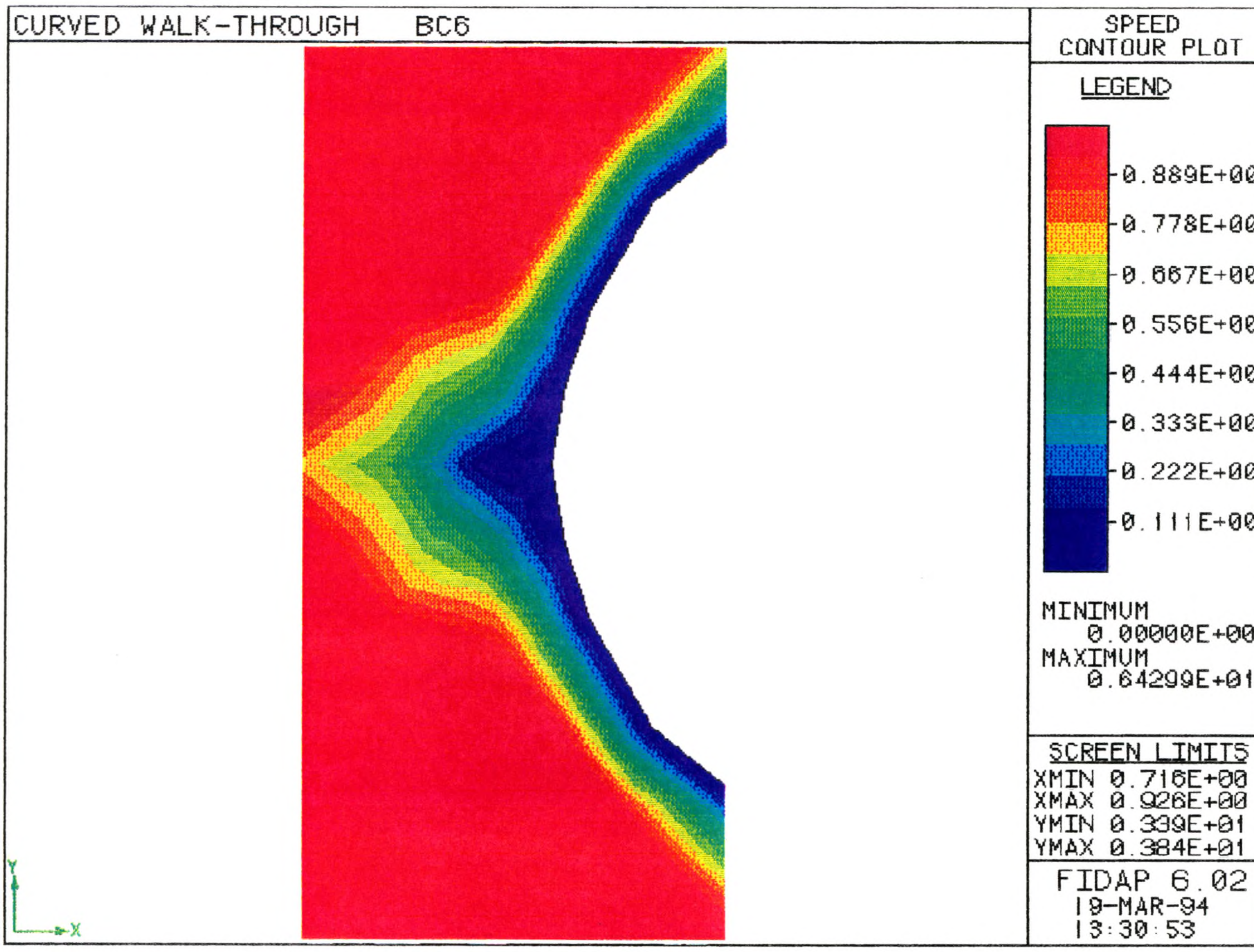

Figure 26: Magnification of the slow-flow layer adjacent to the stagnation point.

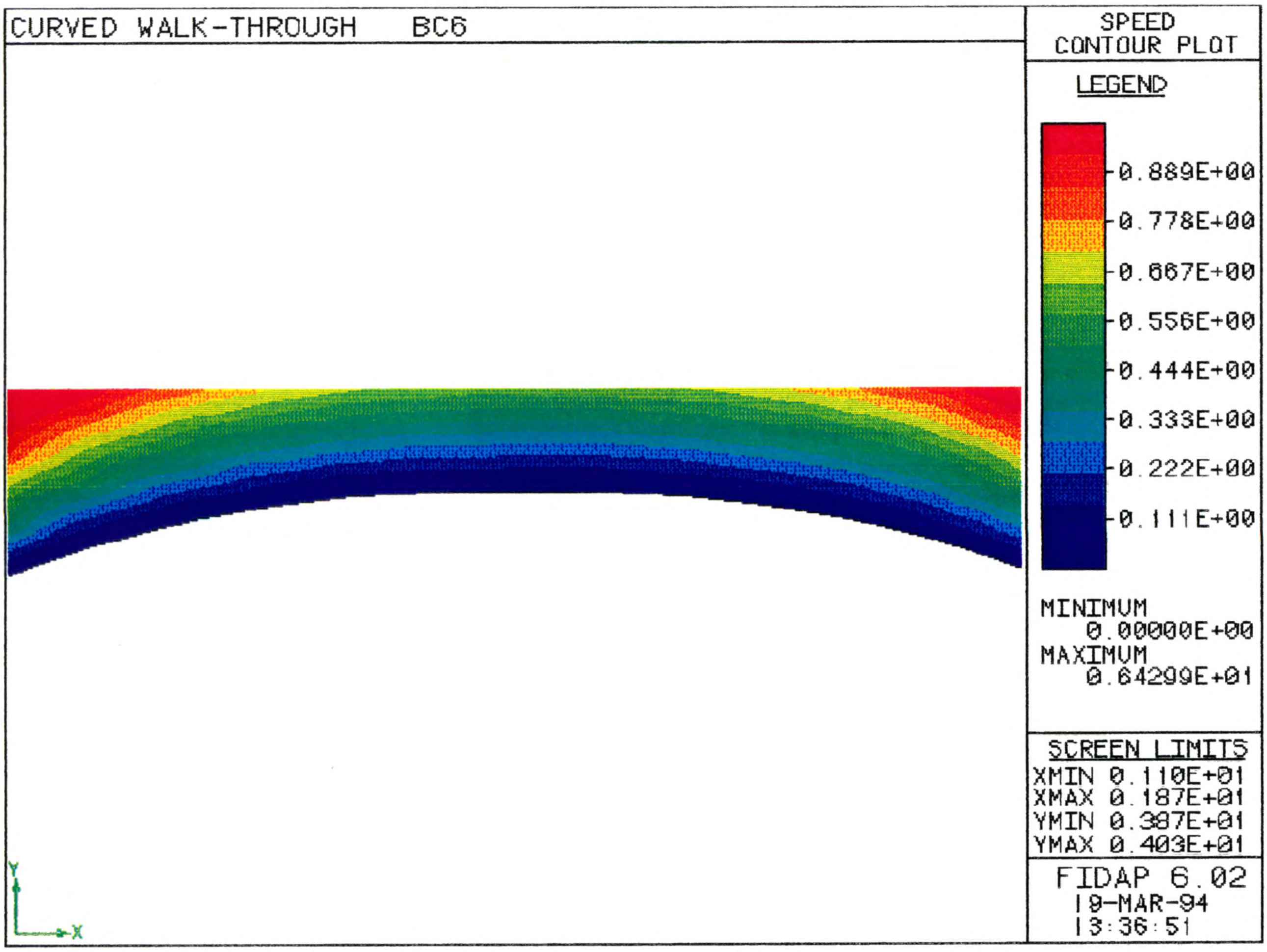

Figure 27: Magnification of the slow-flow layer at the person's back.

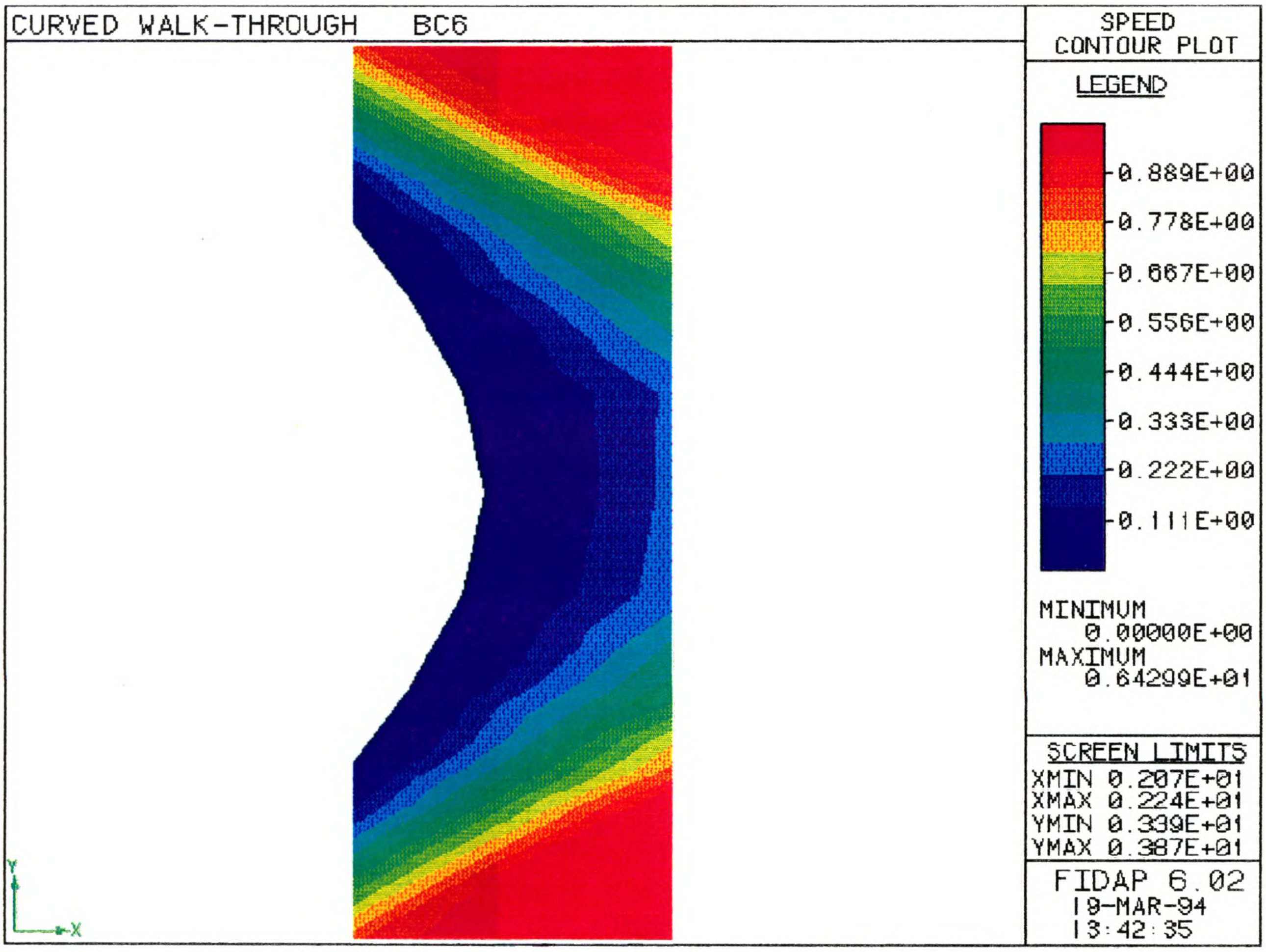

Figure 28: Magnification of the wake.

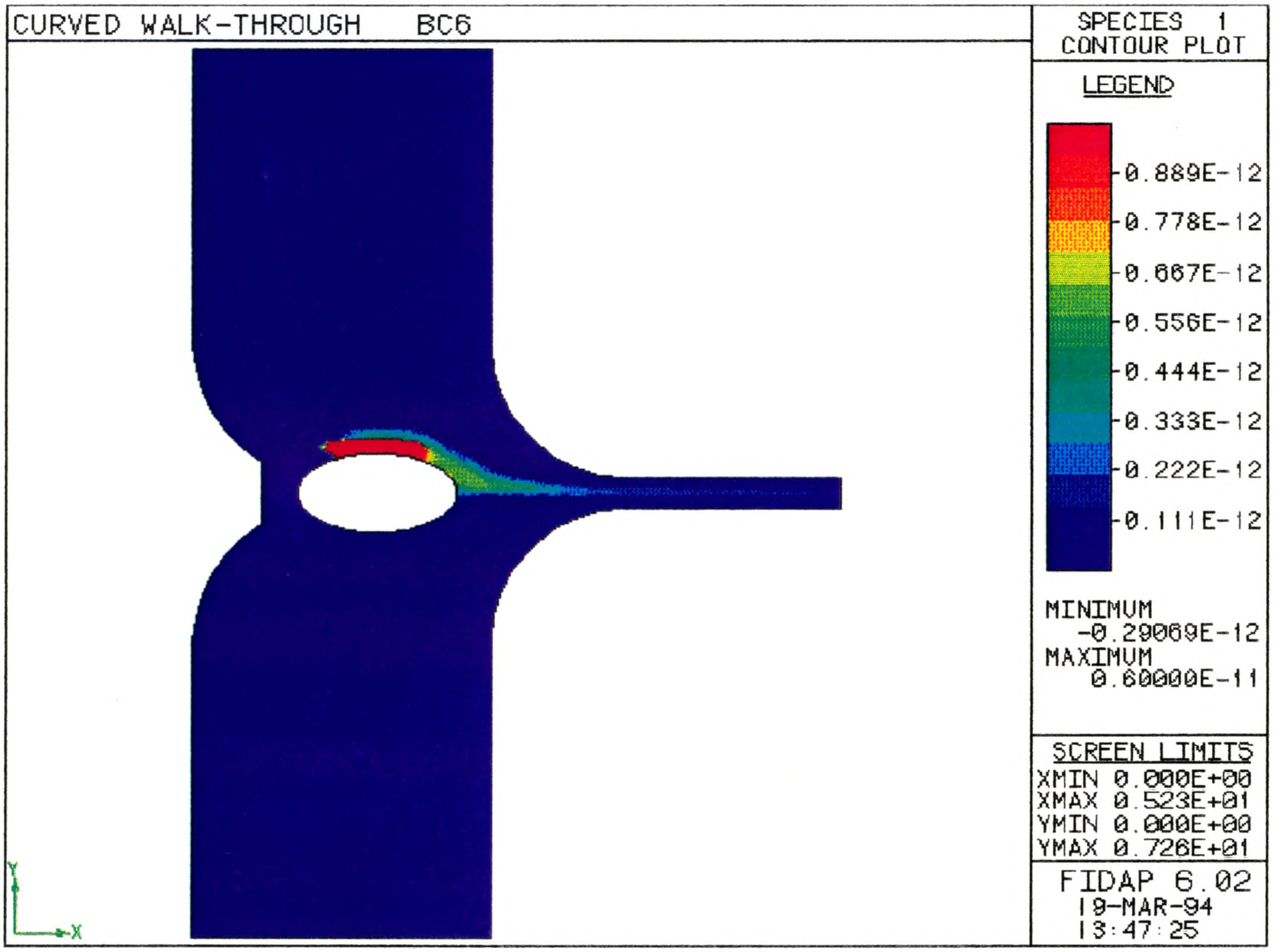

Figure 29: RDX concentration plot.

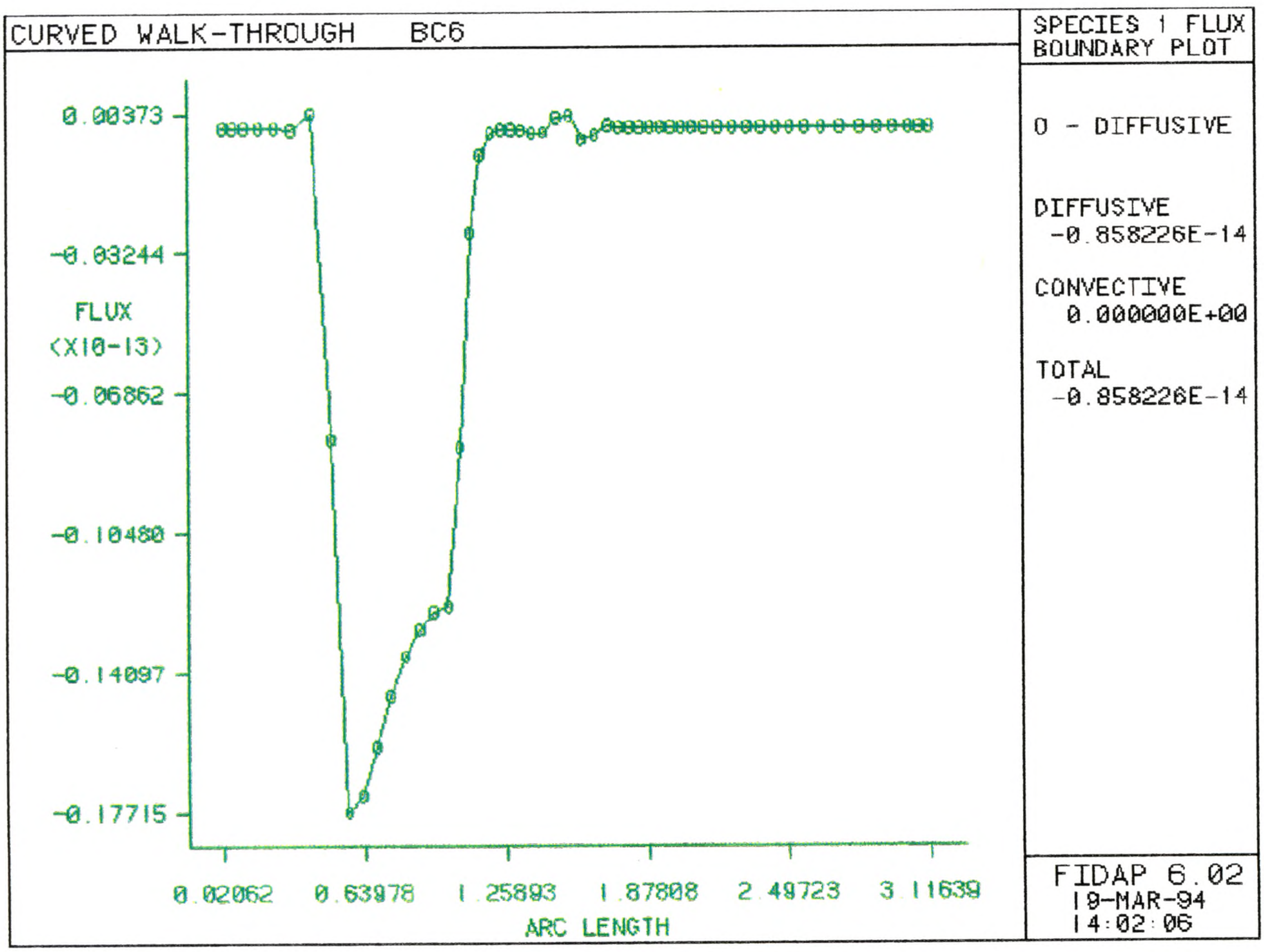

Figure 30: RDX flux plot.

Triangle, Virginia. Figure 31 is a contour plot of airspeed through a straight walk-through portal, 2 feet wide and 3.5 feet long. Air enters from the left at a speed of 2.0 feet per second, and is collected at the right. The person is pictured at mid-portal, turned 90 degrees to present a slimmer profile to the flow. Points "A," "B," and "C" illustrate slow-flow layer thickness at three different locations. Figures 32-34 are further magnifications of the slow-flow layer. From the Screen Limits, the actual magnitude of the various flow areas can be determined. For example, in Figure 32, since YMIN is 0.856 feet and YMAX is 1.15 feet, the plot depicts 0.294 feet of the portal. By scaling, the actual thickness of the slow-flow zone at point "A" can now be determined to be 0.32 inch; according to Table 1, RDX would require about 15 seconds to diffuse at this point, too long for FAA requirements. Similarly, the thickness of the layer at points "B" and "C" can be determined using Figures 33 and 34. Therefore as configured, this portal is unacceptable.

Figure 35 is a plot of RDX concentration in the portal, if a six inch lamina of RDX is placed at the person's side. The explosive is situated at the red area near the person's side. Figure 36 is a plot of the flux of explosives vapor emitted from different locations along the explosive. The flux varies from 0 at the edges of the explosive to 0.206×10^{-13} near the mid point. At steady state, a total of 0.645×10^{-14} pound of RDX is emitted per second. As the size of the wake is reduced in succeeding runs, this

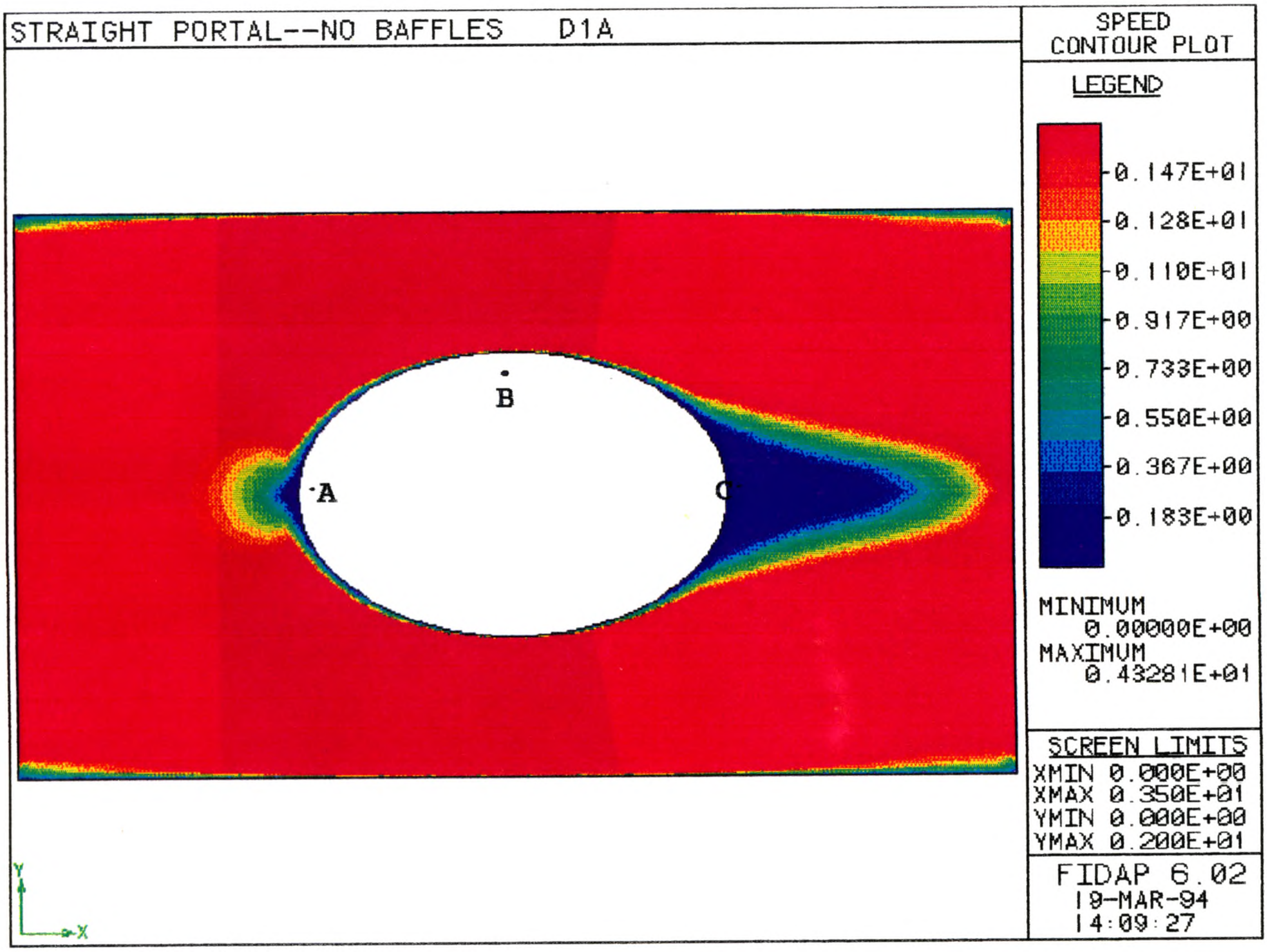

Figure 31: Speed plot of a straight walk-through portal.

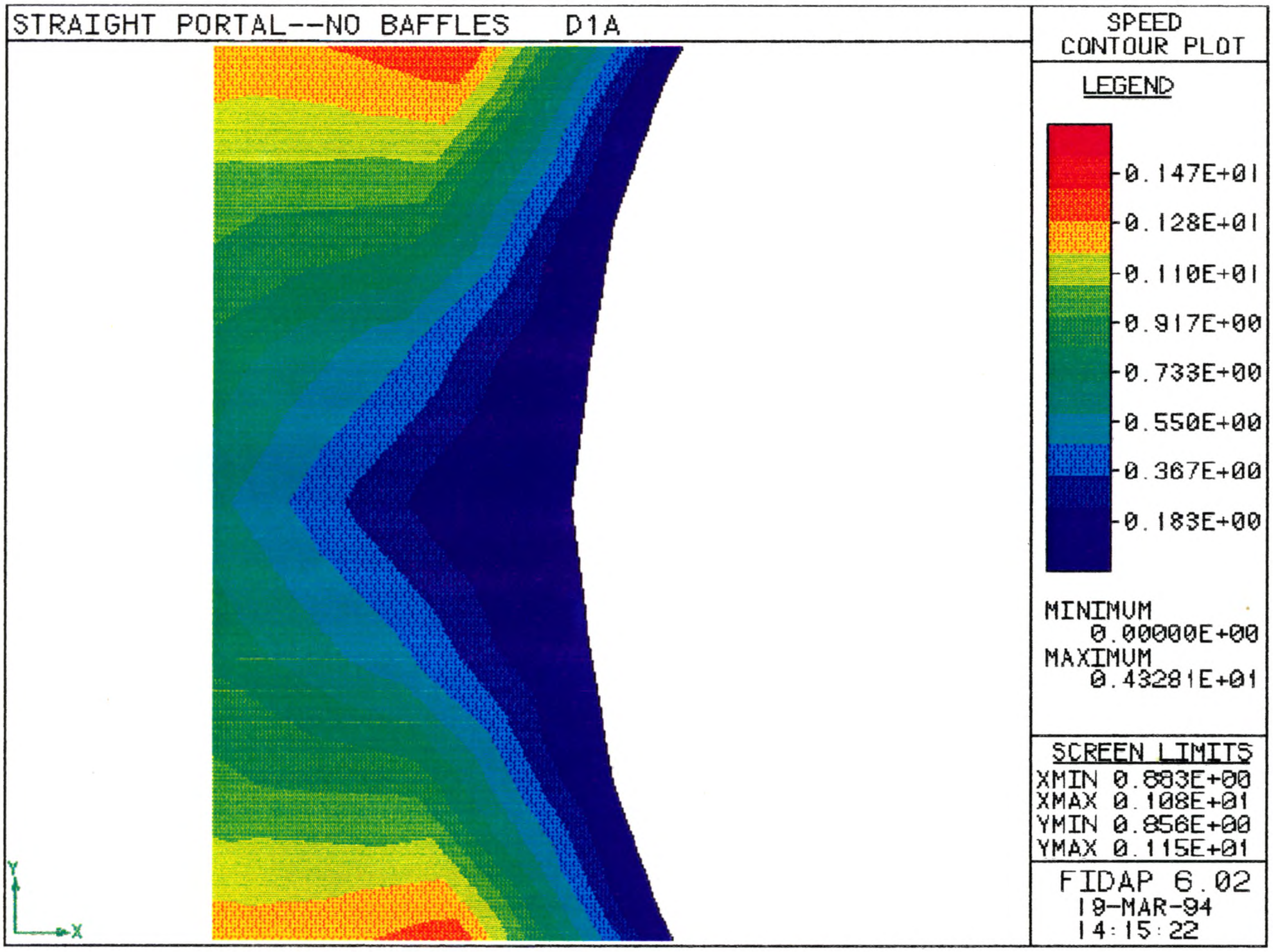

Figure 32: Magnification of the slow-flow layer adjacent to the stagnation point.

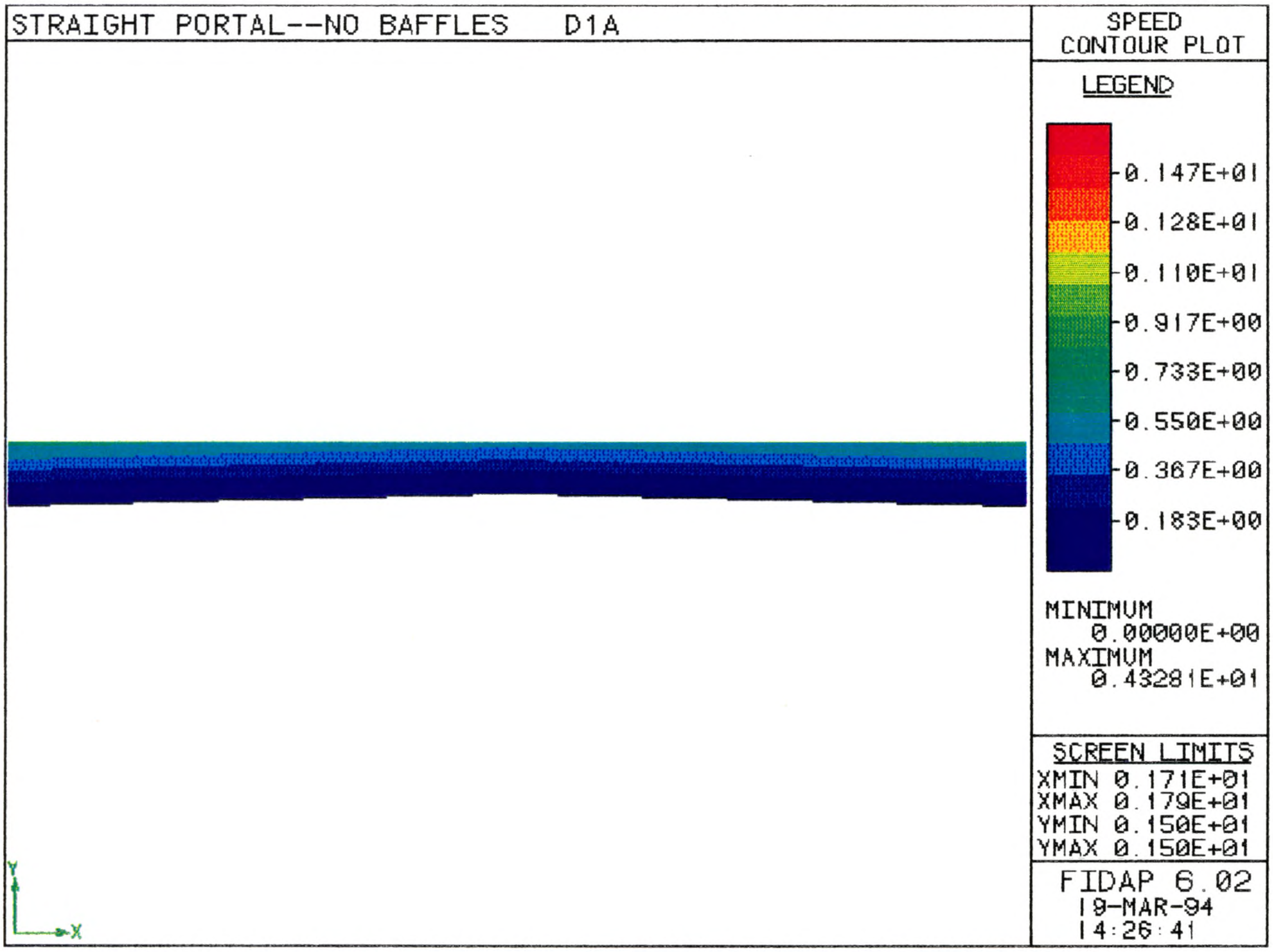

Figure 33: magnification of the slow-flow layer at the person's back.

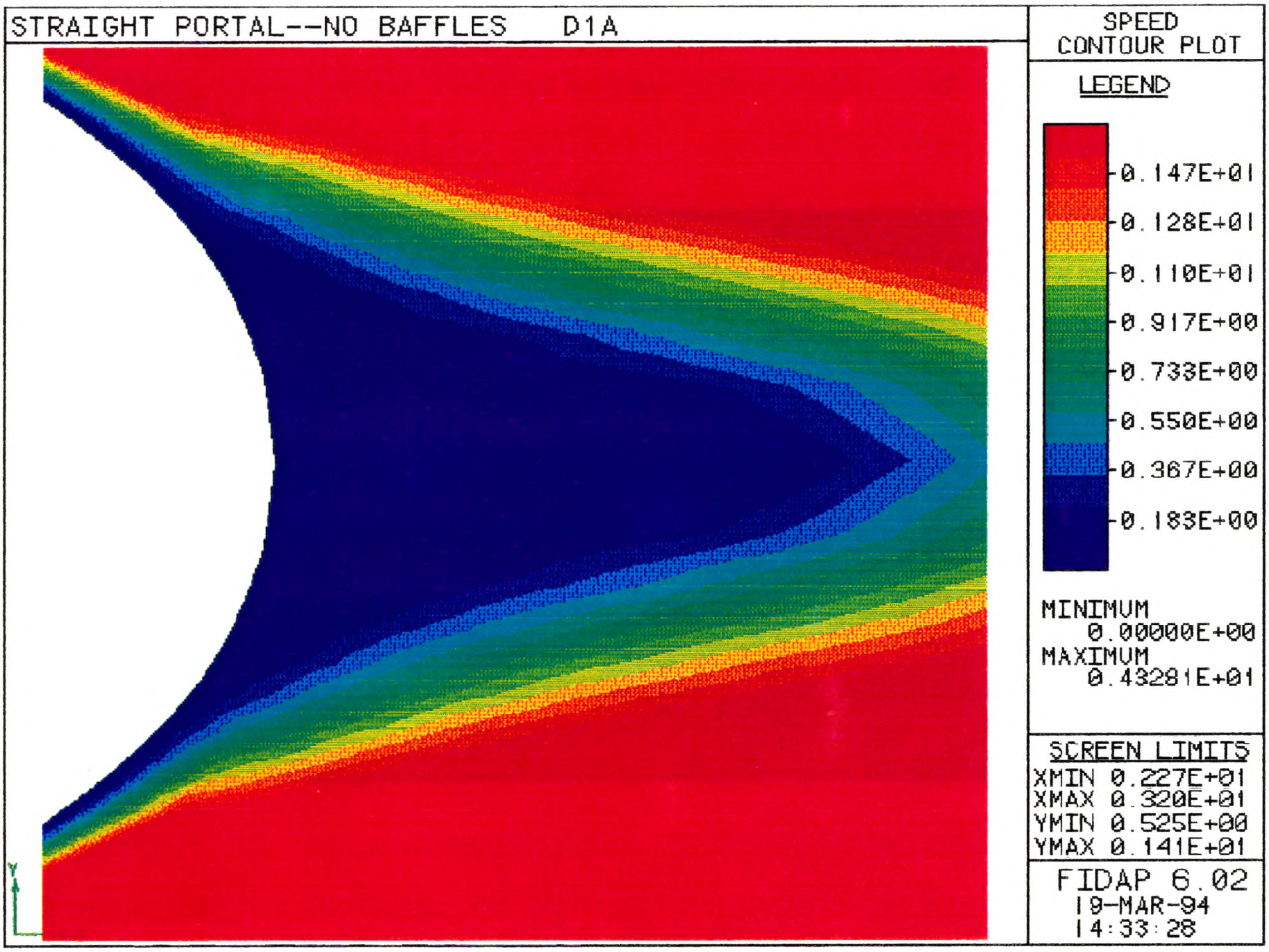

Figure 34: Magnification of the wake.

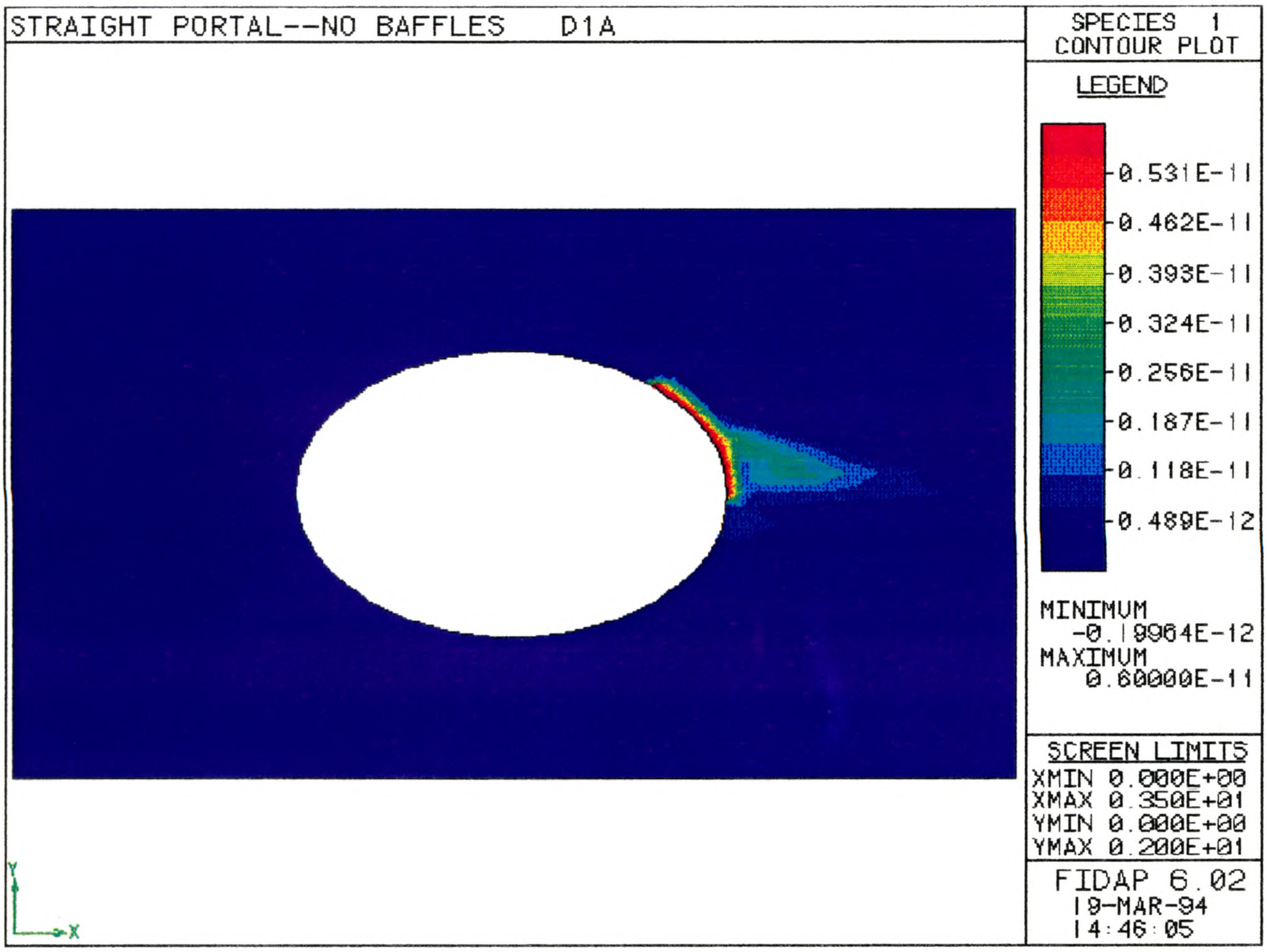

Figure 35: RDX concentration plot.

value should increase since mass flux increases with increasing air flow.

Figure 37 is a contour speed plot of a wedge-shaped portal with the same volummetric flow rate as the previous portal. The purpose of the wedge is to reduce the size of the trailing wake, by directing the air streams from above and below the person to converge sooner. The wedge, by itself, does not affect the size of the slow-flow layer at the stagnation point and at the person's front and back. Figure 38 is an enlargement of the area around the wake. From the Screen Limits, since YMIN is 1.71 feet and YMAX is 2.27 feet, the plot depicts 0.56 feet of this portal. By scaling, the actual size of the wake at point "A" can now be determined to be 1.15 inches. The wake has been reduced from 6.2 inches in the straight portal to 1.15 inches here, still far from the goal of 0.2 inch.

Figure 39 is a plot of RDX concentration in the portal using an RDX lamina identical to the one used in the straight portal. Figure 40 is a plot of the flux of explosives vapor emitted from different locations along the explosive. The flux varies from 0 at the edge of the explosive to 0.237×10^{-13} near the mid point. At steady state, a total of 0.910×10^{-14} pound of RDX is emitted per second. This represents a rather substantial improvement of 41% over the straight-walled portal.

Since the exit size keeps one from increasing the angle of the wedge, another method must be found to constrict flow. One way to do so is by the use of baffles. Baffles are useful because they

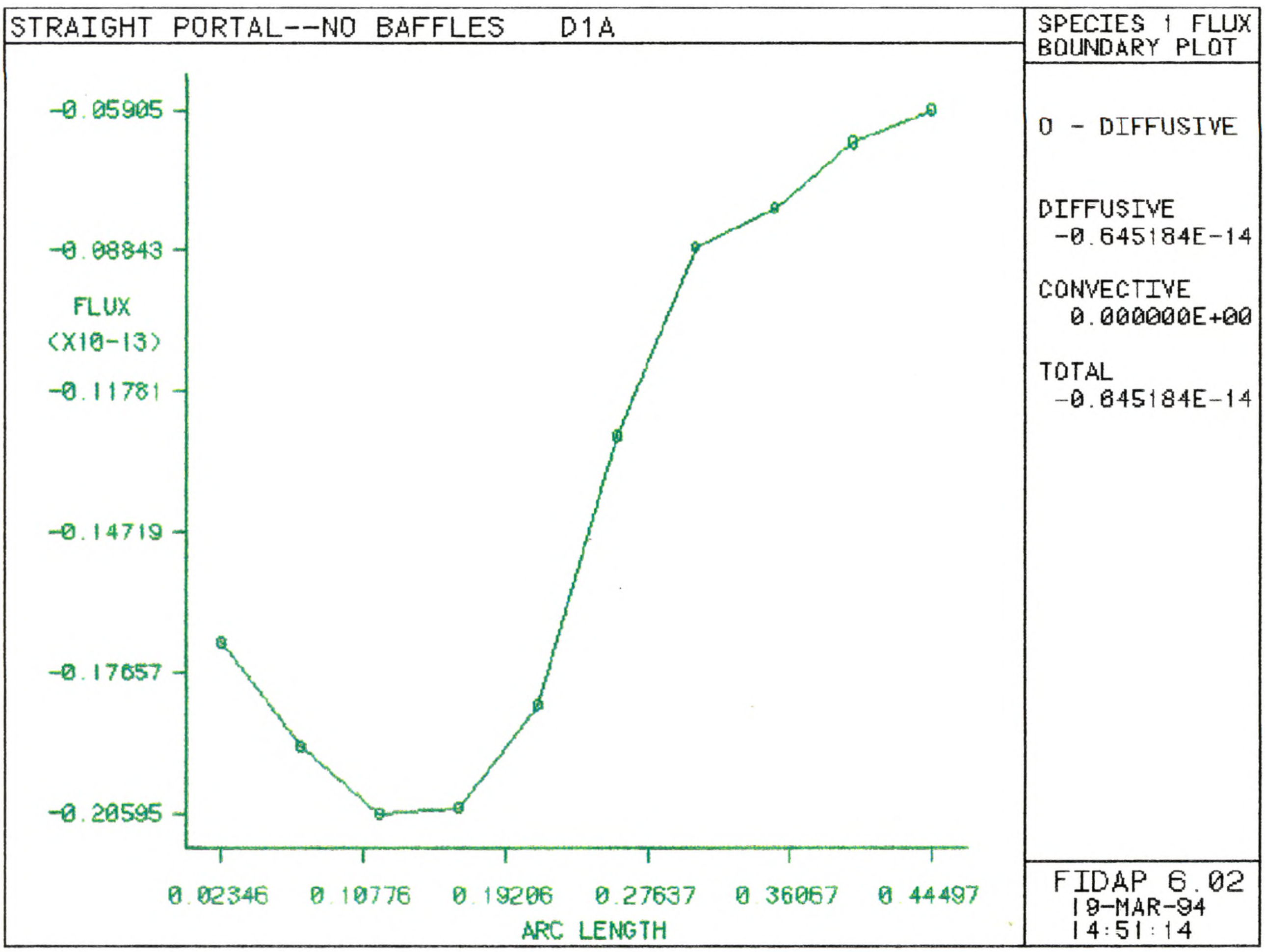

Figure 36: RDX flux plot.

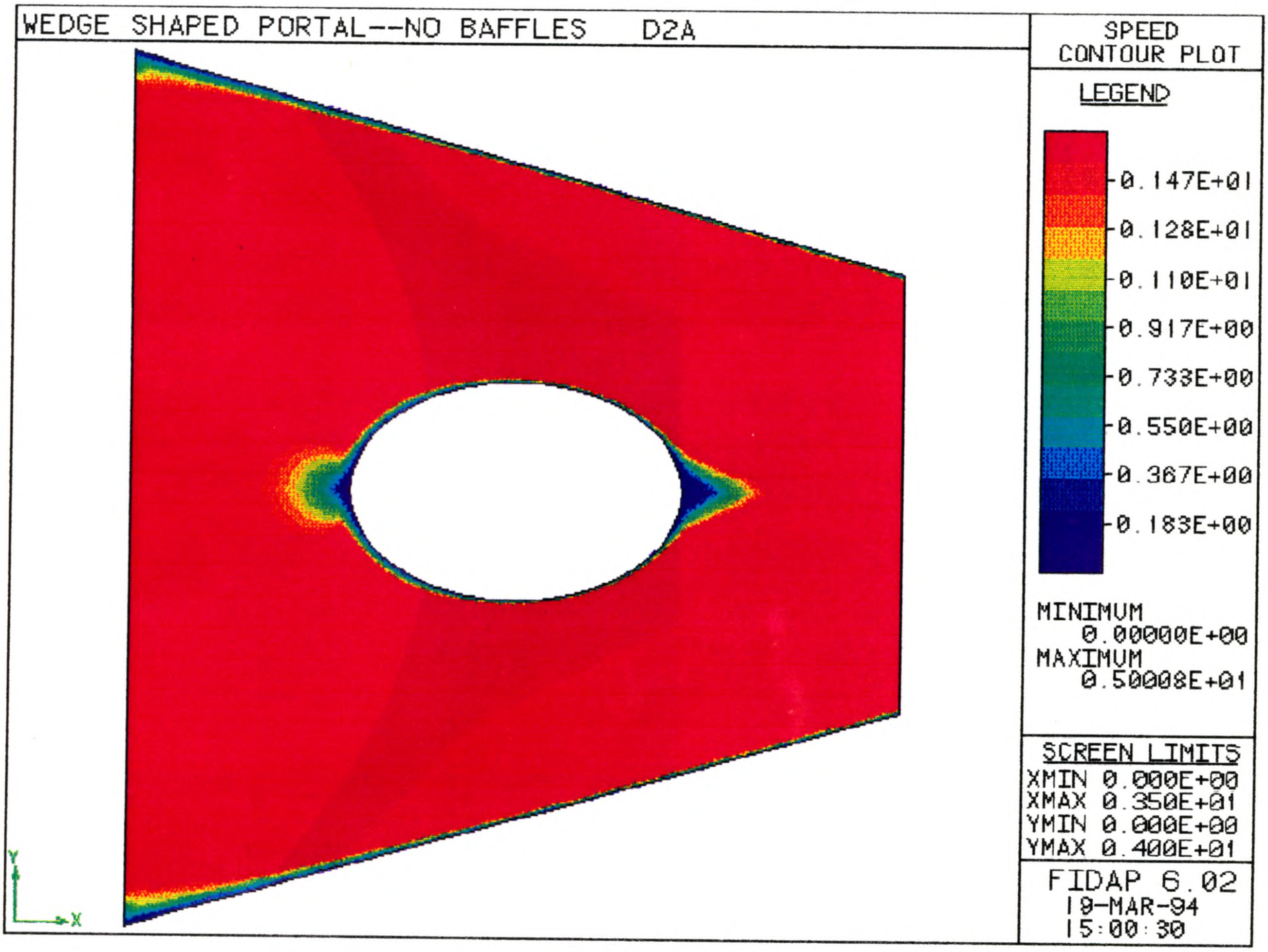

Figure 37: Speed plot of a wedge-shaped walk-through portal.

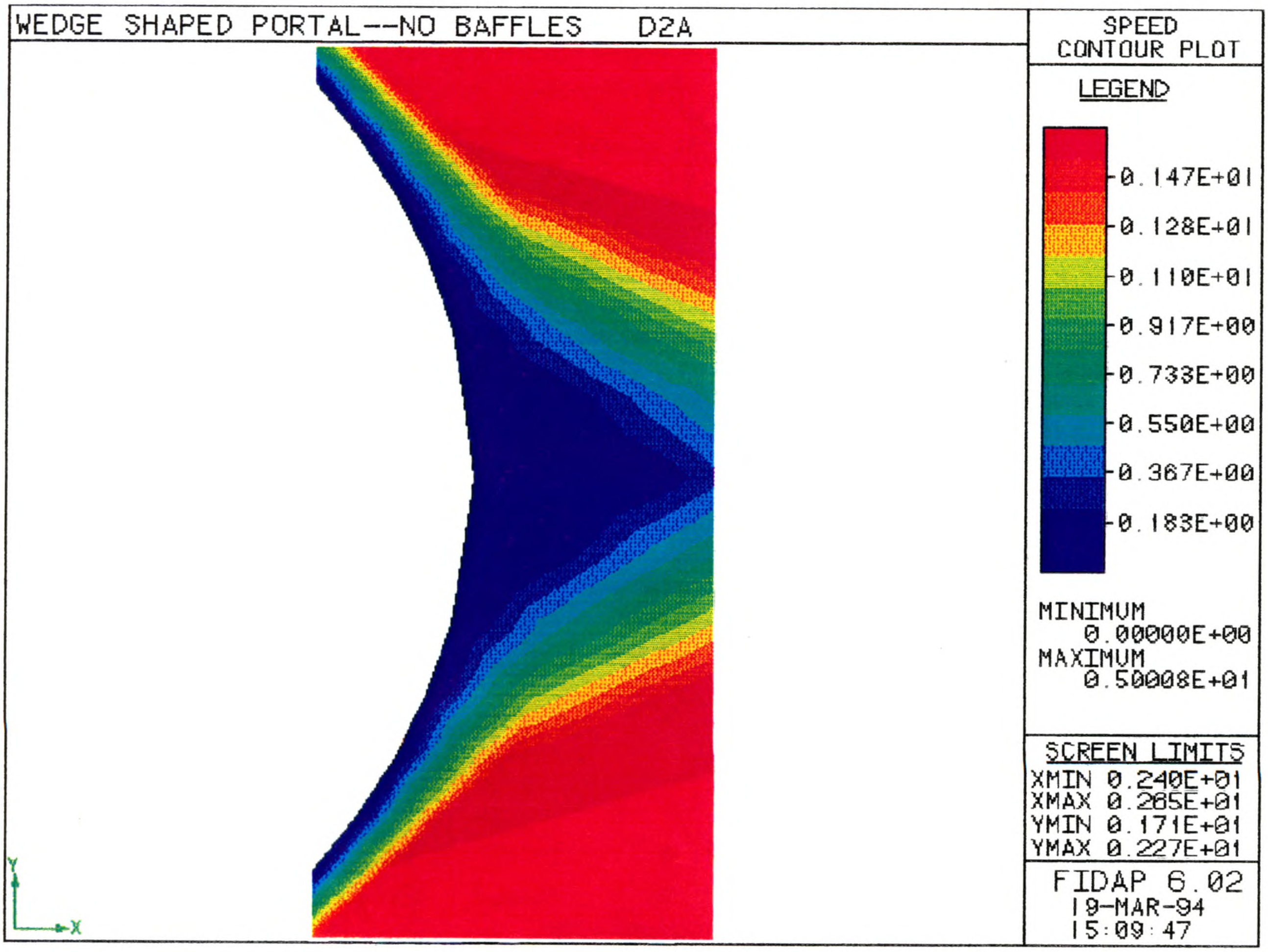

Figure 38: Magnification of the wake.

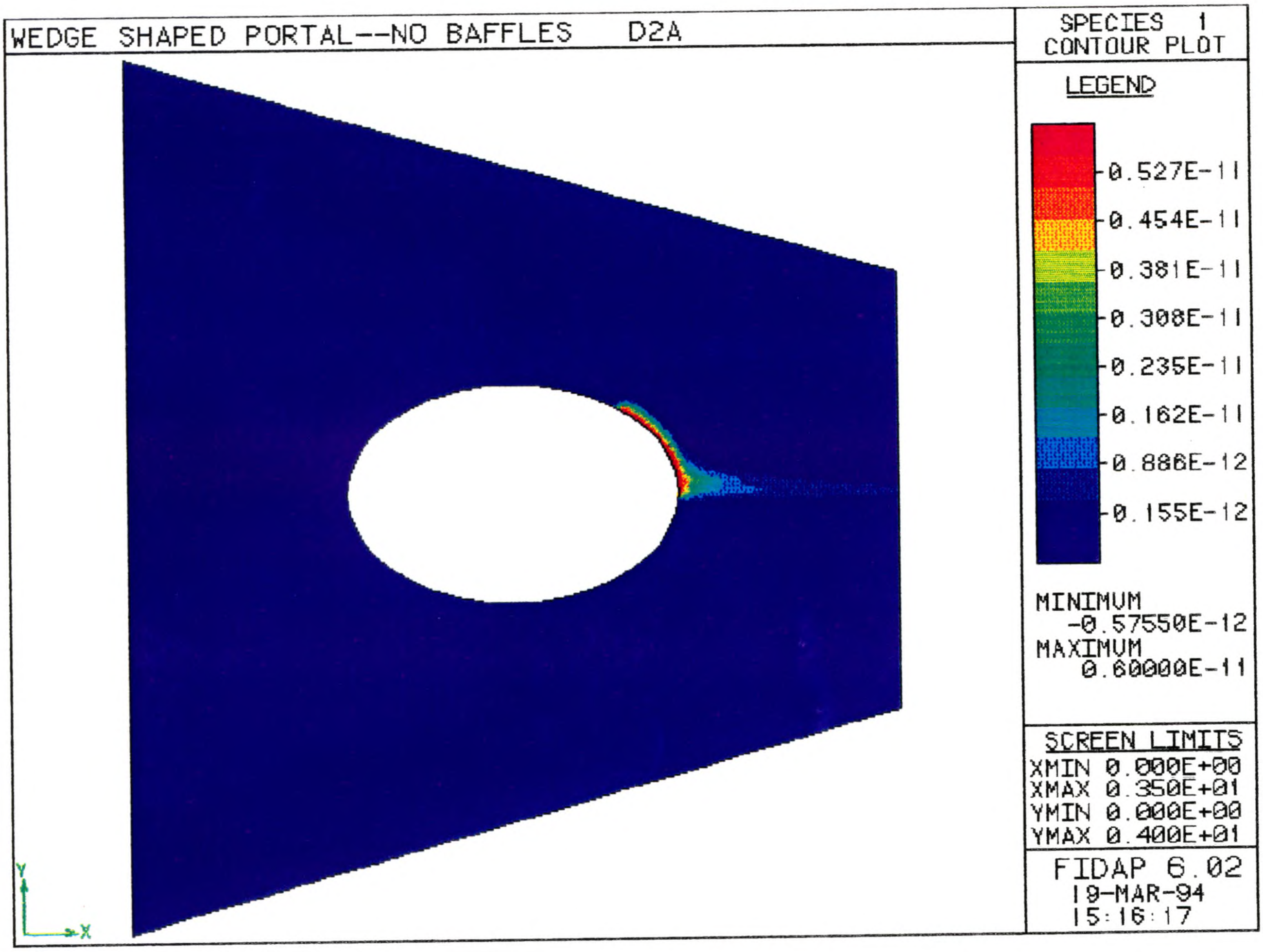

Figure 39: RDX concentration plot.

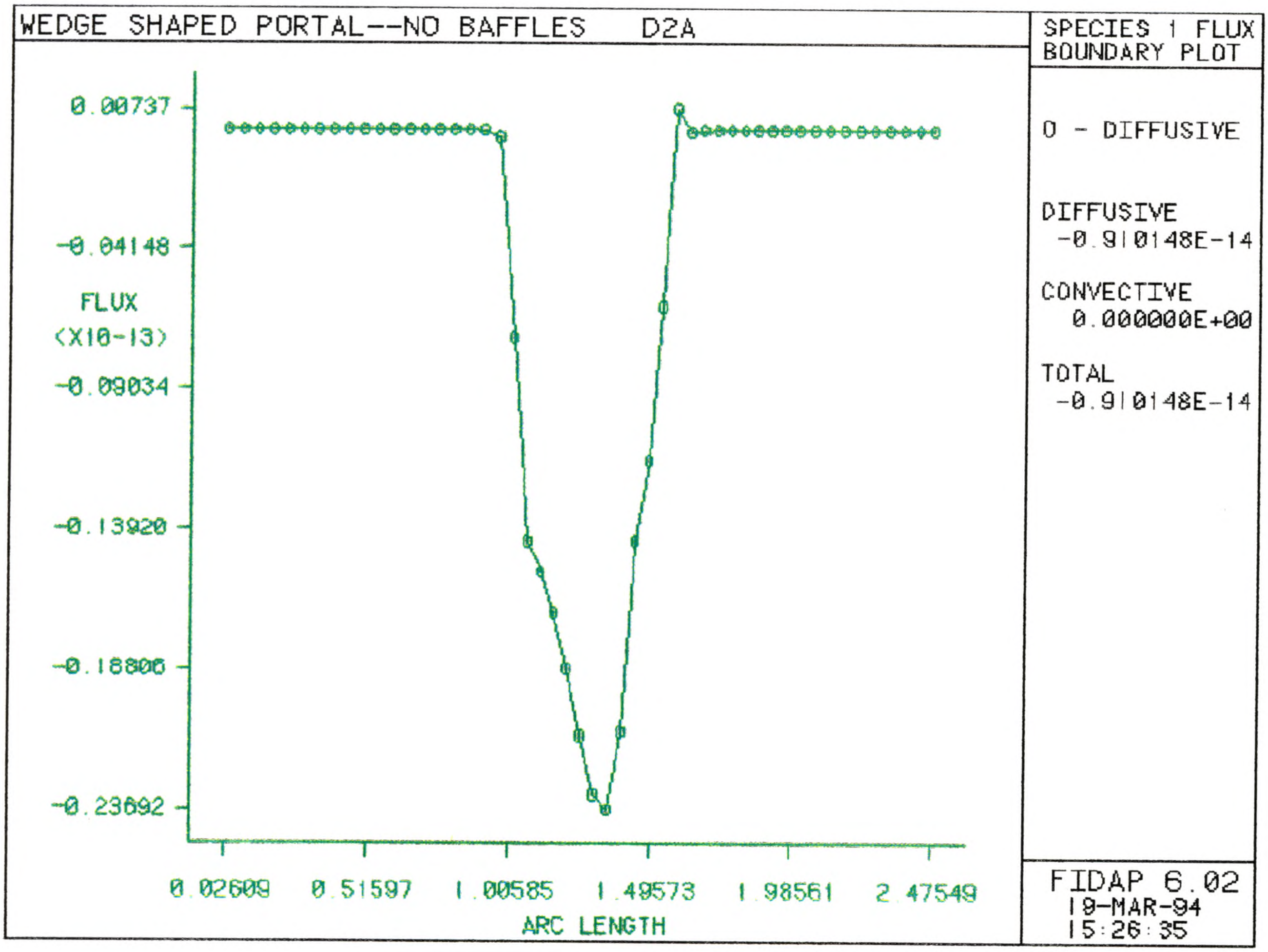

Figure 40: RDX flux plot.

can also direct flow at the stagnation point. Figure 41 is a contour plot of airspeed in a wedge-shaped portal with upstream baffles. These baffles are an attempt to reduce the size of the slow-flow layer at the stagnation point. The baffles do seem to reduce the layer. A magnification of this layer is given later in Figure 48.

Figure 42 shows the wedge with both upstream and downstream baffles. The downstream baffles are to further reduce the trailing wake. They were purposely kept small to ensure that the person could turn 90 degrees and walk out of the portal. These baffles turned out to be too small to greatly affect the size of the wake. There is little difference between the size of the wakes in figures 41 and 42.

Figure 43 is a contour plot of airspeed in the wedge-shaped portal with enlarged downstream baffles. These baffles would have to be retractable since their size prevents the person from turning 90 degrees and exiting the portal. Figure 44 is a magnification of the slow-flow layer adjacent to the stagnation point. From the Screen Limits, since YMIN is 1.73 feet and YMAX is 2.26 feet, the plot depicts 0.53 feet of the portal. By scaling, the actual thickness of the slow-flow layer can now be determined to be 0.042 inch. The upstream baffles greatly reduced the layer here from 0.32 inch in the baffle-less portal.

Figure 45 is a magnification of the wake. The extra-large baffles helped to reduce the size of the wake from 1.15 inches to 0.051 inch. According to Table 1, this reduces the time RDX

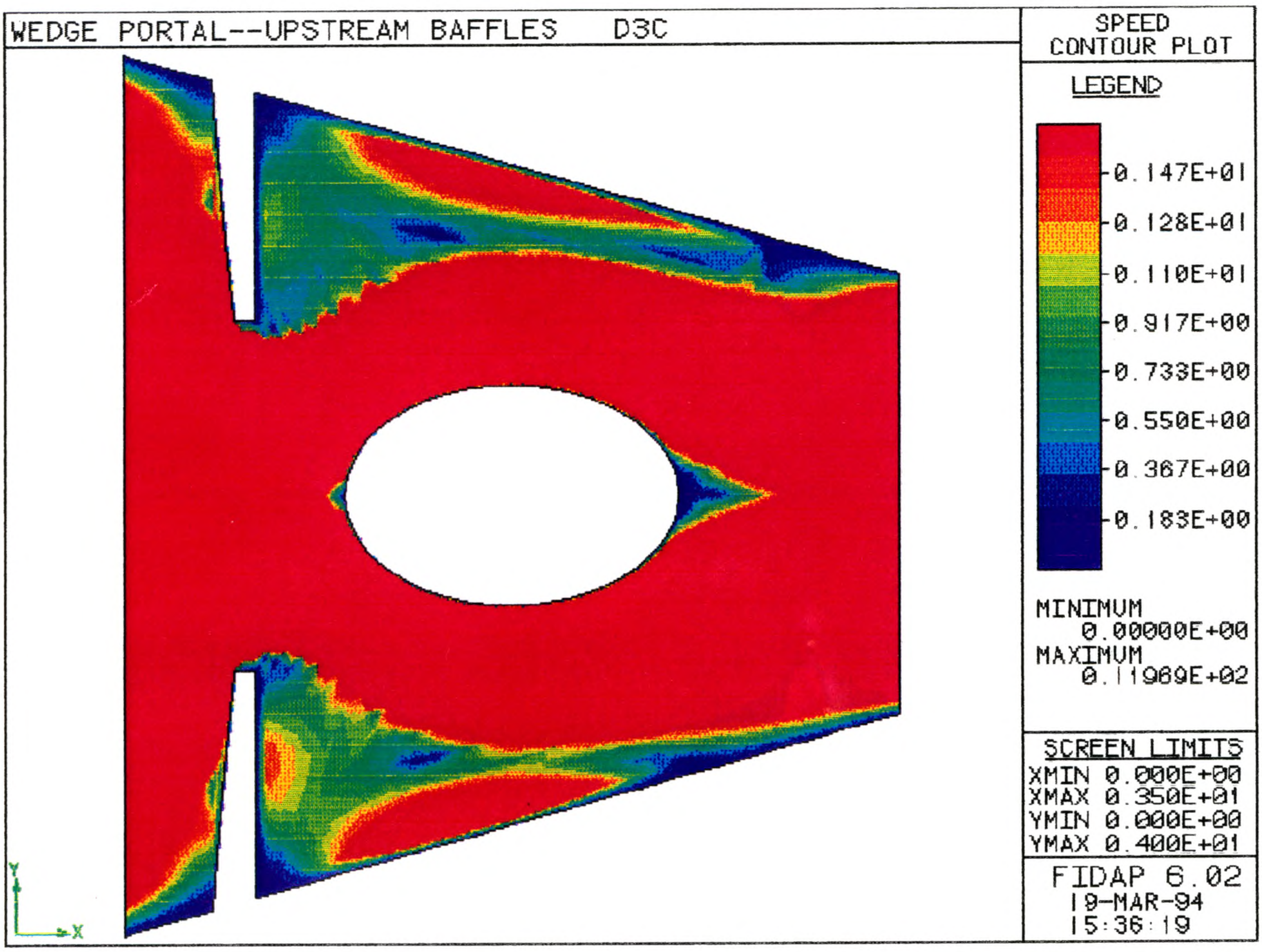

Figure 41: Speed plot of a wedge-shaped portal with upstream baffles.

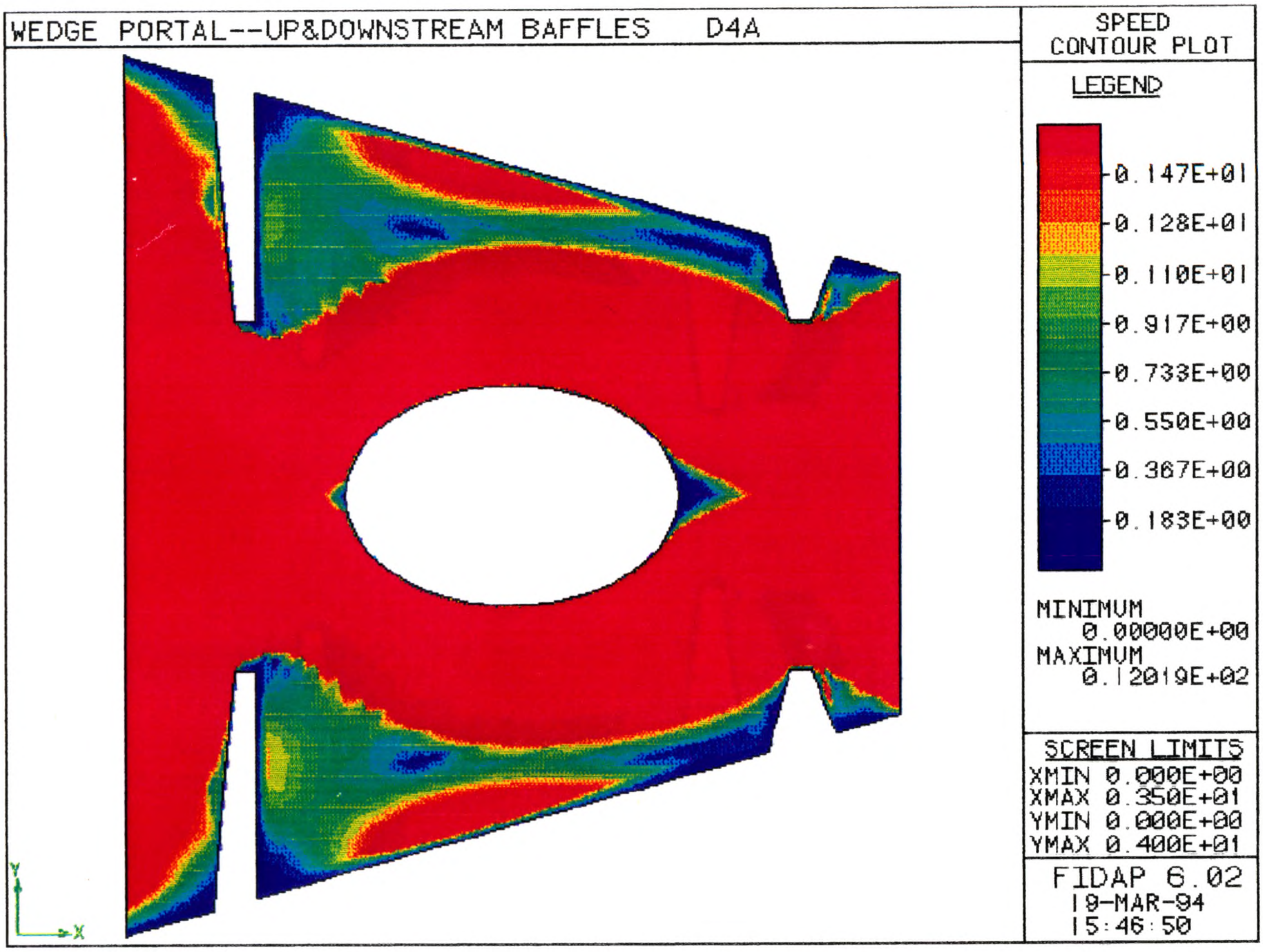

Figure 42: Speed plot of wedge-shaped portal with upstream and downstream baffles.

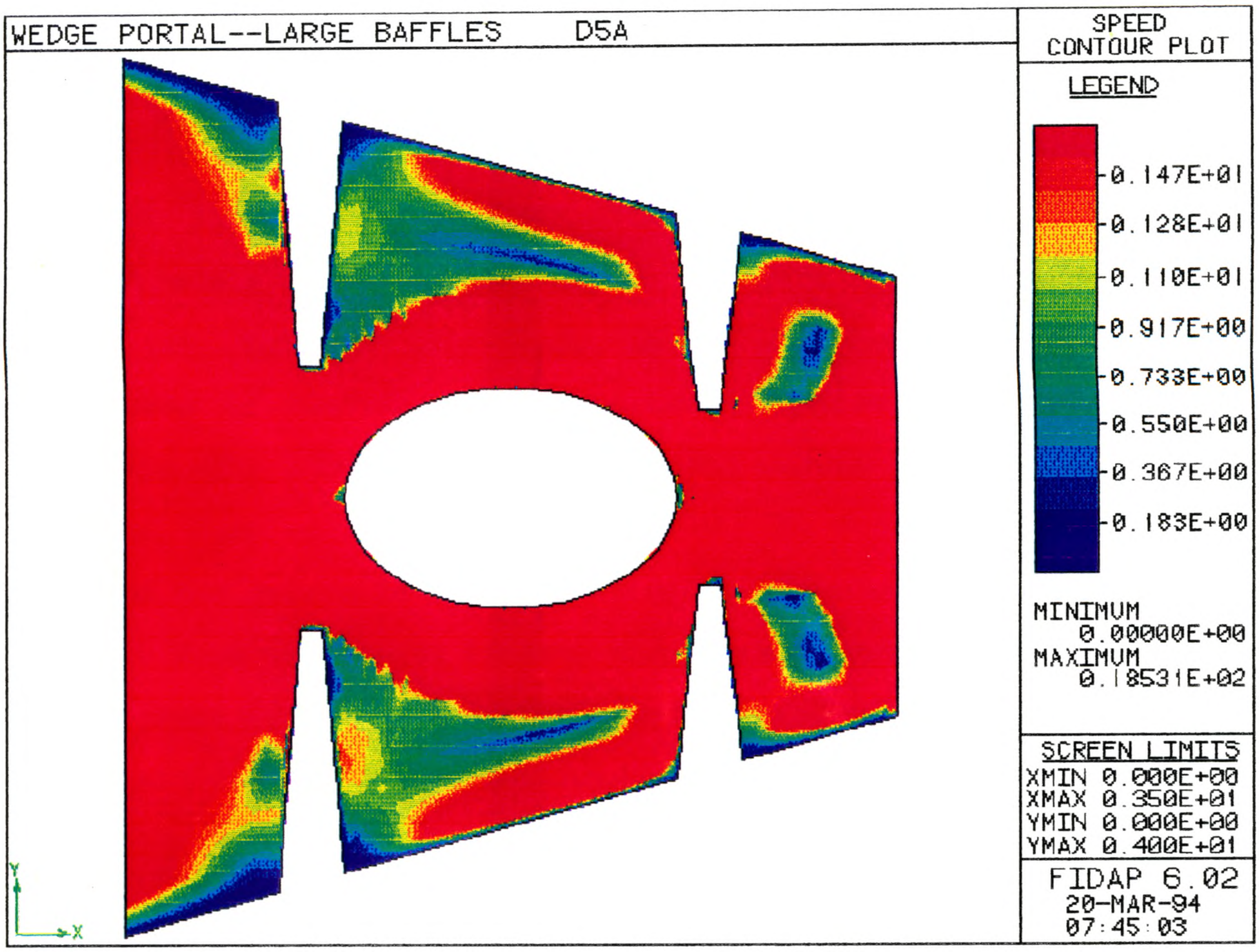

Figure 43: Speed plot of wedge-shaped portal with large baffles.

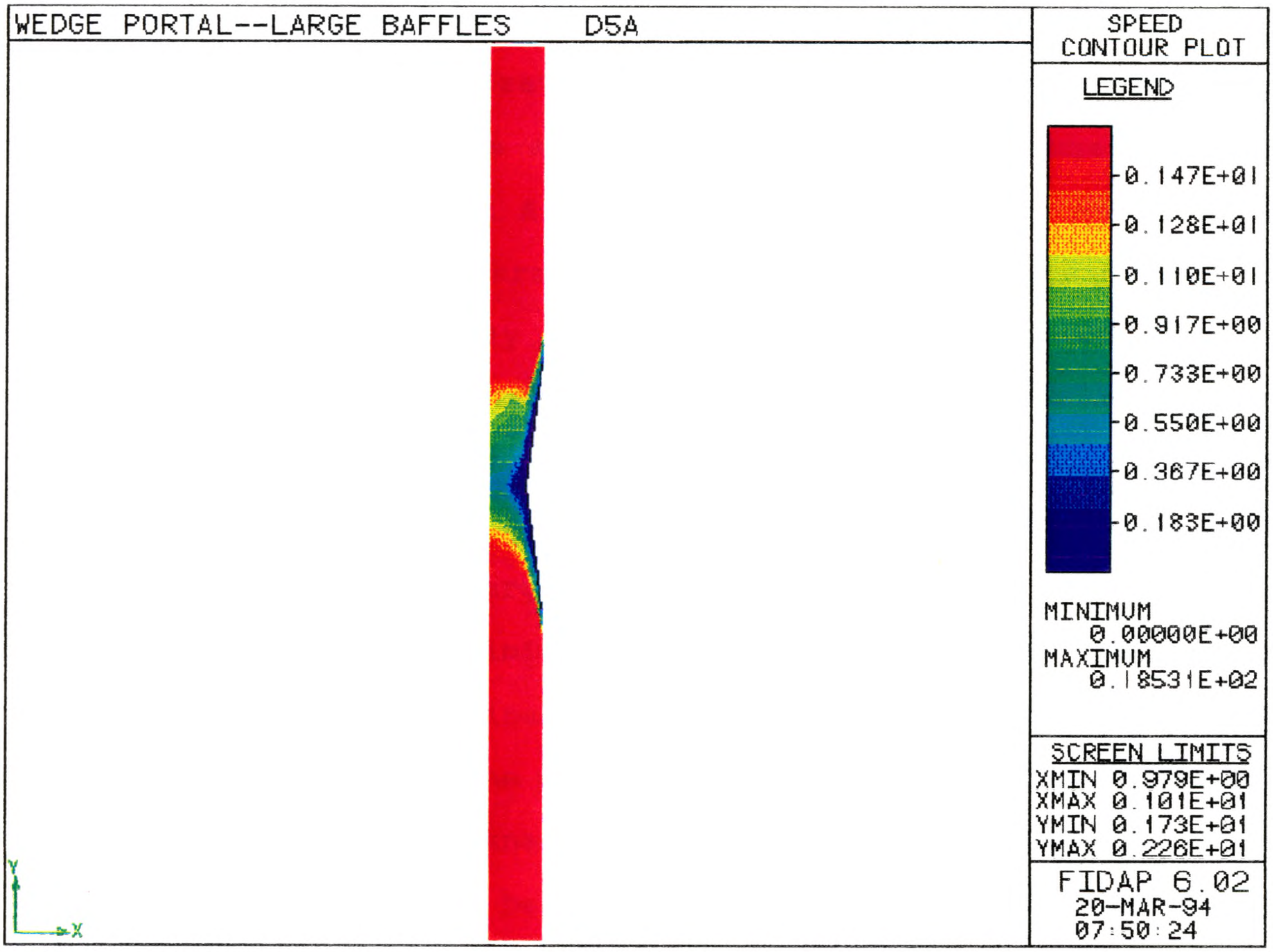

Figure 44: Magnification of the slow-flow layer adjacent to the stagnation point.

diffuses from three minutes to one second. The slow-flow zone is now less than 0.2 inch at all points, within FAA requirements. Figure 46 is a plot of the flux of explosives vapor emitted from different locations along the explosive. The flux varies from 0 at the edges of the explosive to 0.724×10^{-13} near the mid point. At steady state, 0.168×10^{-13} pound of RDX is emitted per second. This is 2.6 times larger than the flux from the straight portal.

Figures 47-51 depict a revolving door portal. Using a revolving door, one can limit the amount of outside air. Figure 47 is a contour plot of airspeed. Air is introduced by a blower at the left and travels past the person to the exit. Since this portal is enclosed, the air supply can be totally controlled. It can be scrubbed or heated, and its speed and direction can be easily varied. With careful design, the total volume of air in the booth can be sampled with little dilution. In Figures 48-50 the area around the person is enlarged in order to better view the slow-flow layer. From the Screen Limits, the actual magnitude of the various flow areas can be determined. In Figure 48, since YMIN is 2.07 feet and YMAX is 2.18 feet, the plot depicts 0.11 foot of the portal. By scaling, the actual thickness of the slow-flow zone adjacent to the stagnation point can now be determined to be 0.011 inch. Similarly, the thickness of the layer at the person's front and back, and the size of the wake can be determined. The size of the entire slow-flow zone is well within the FAA requirement of 0.2 inch. Figure 51 is a velocity vector plot of the lower corner of the portal. The colored arrows give the speed of the flow as well as its direction.

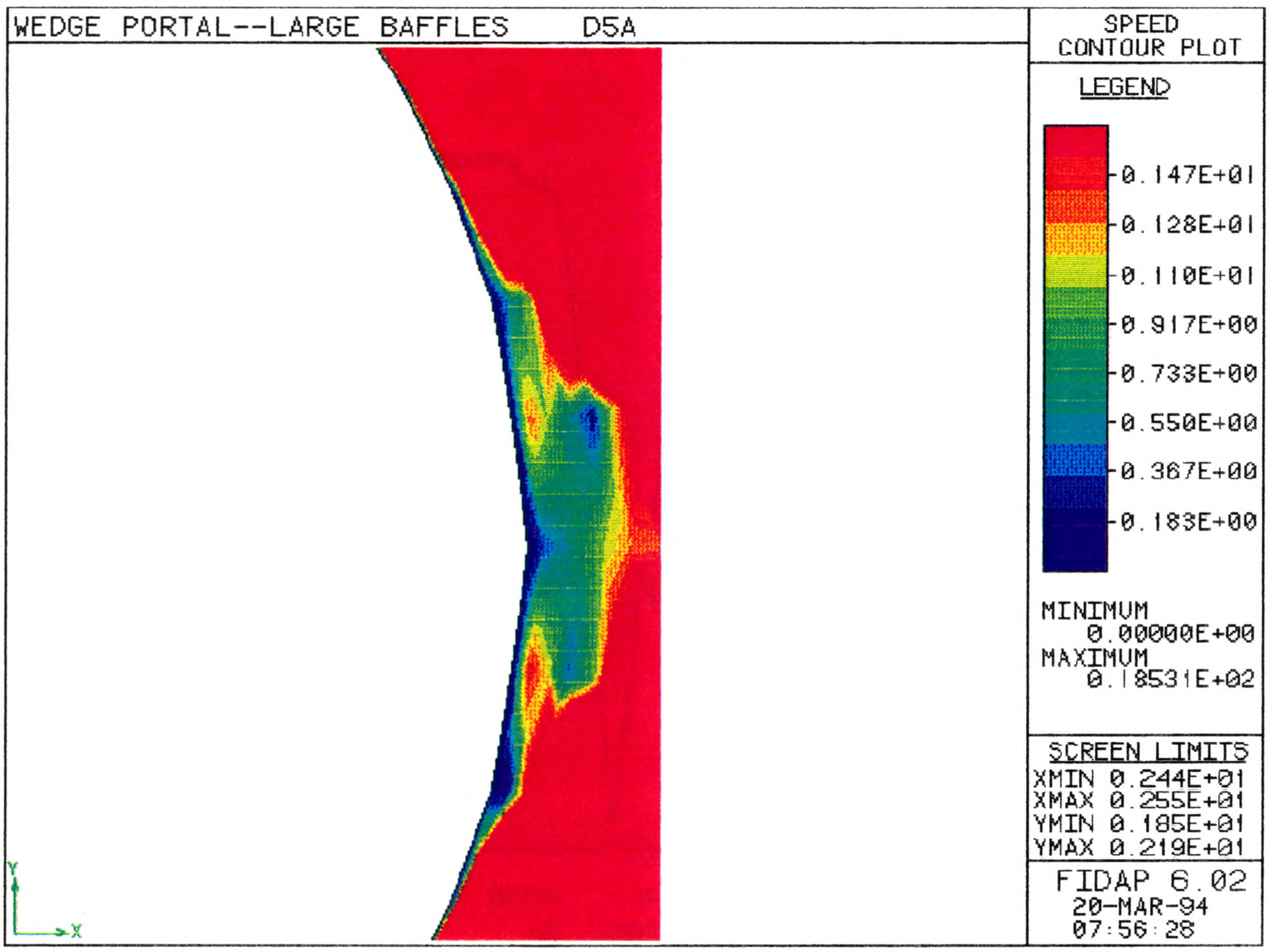

Figure 45: Magnification of the wake.

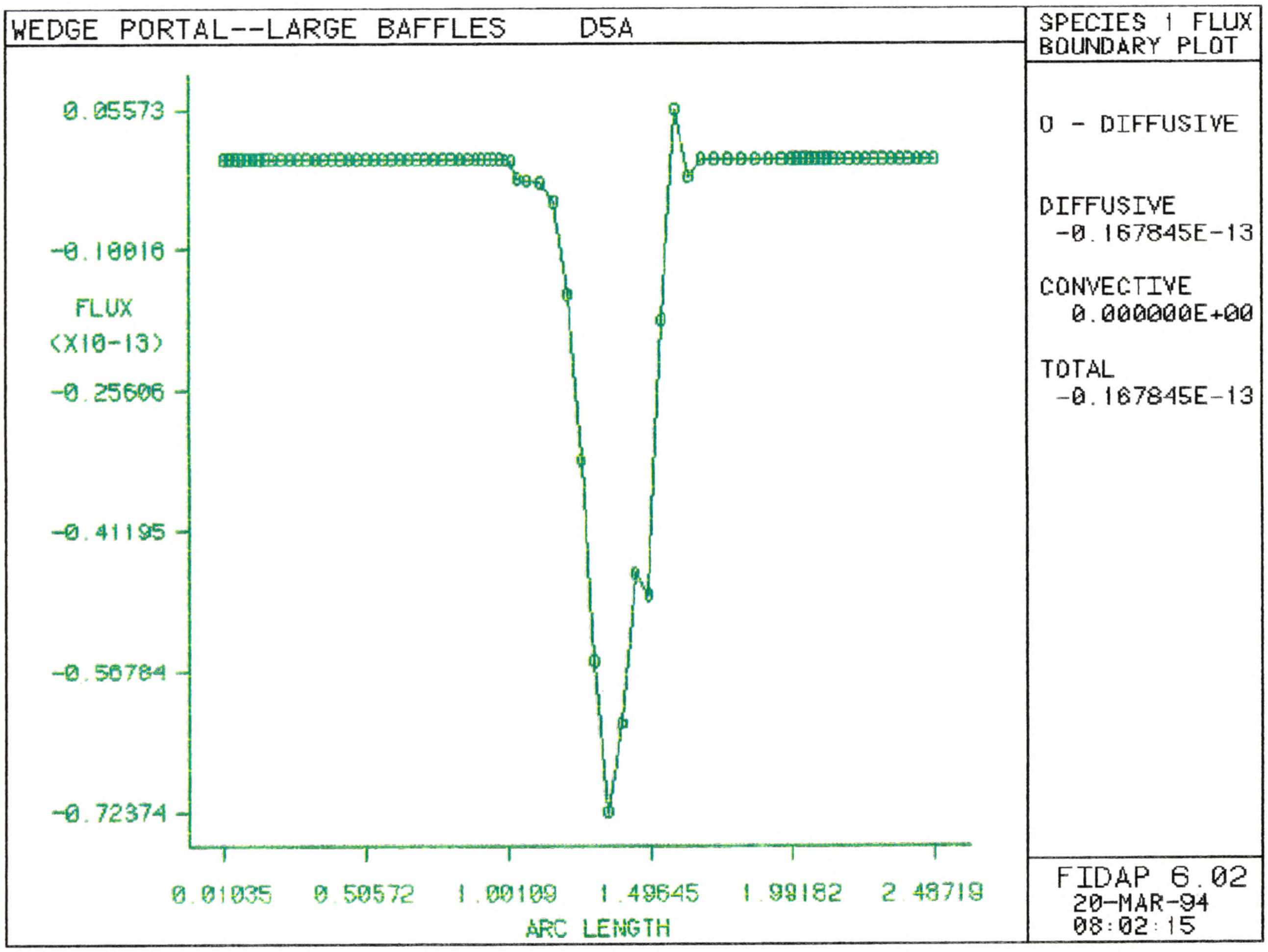

Figure 46: RDX flux plot.

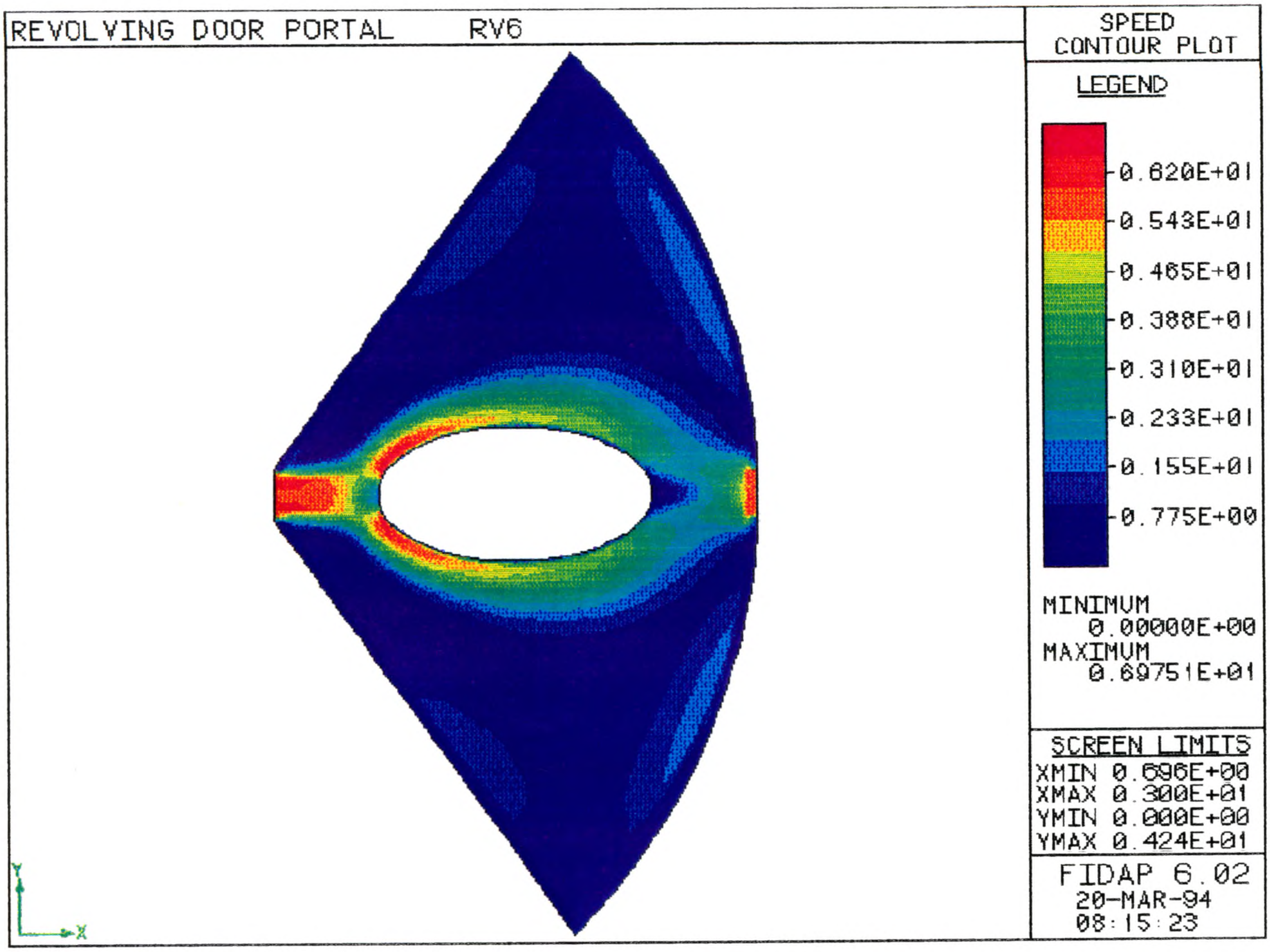

Figure 47: Speed plot of a revolving door portal.

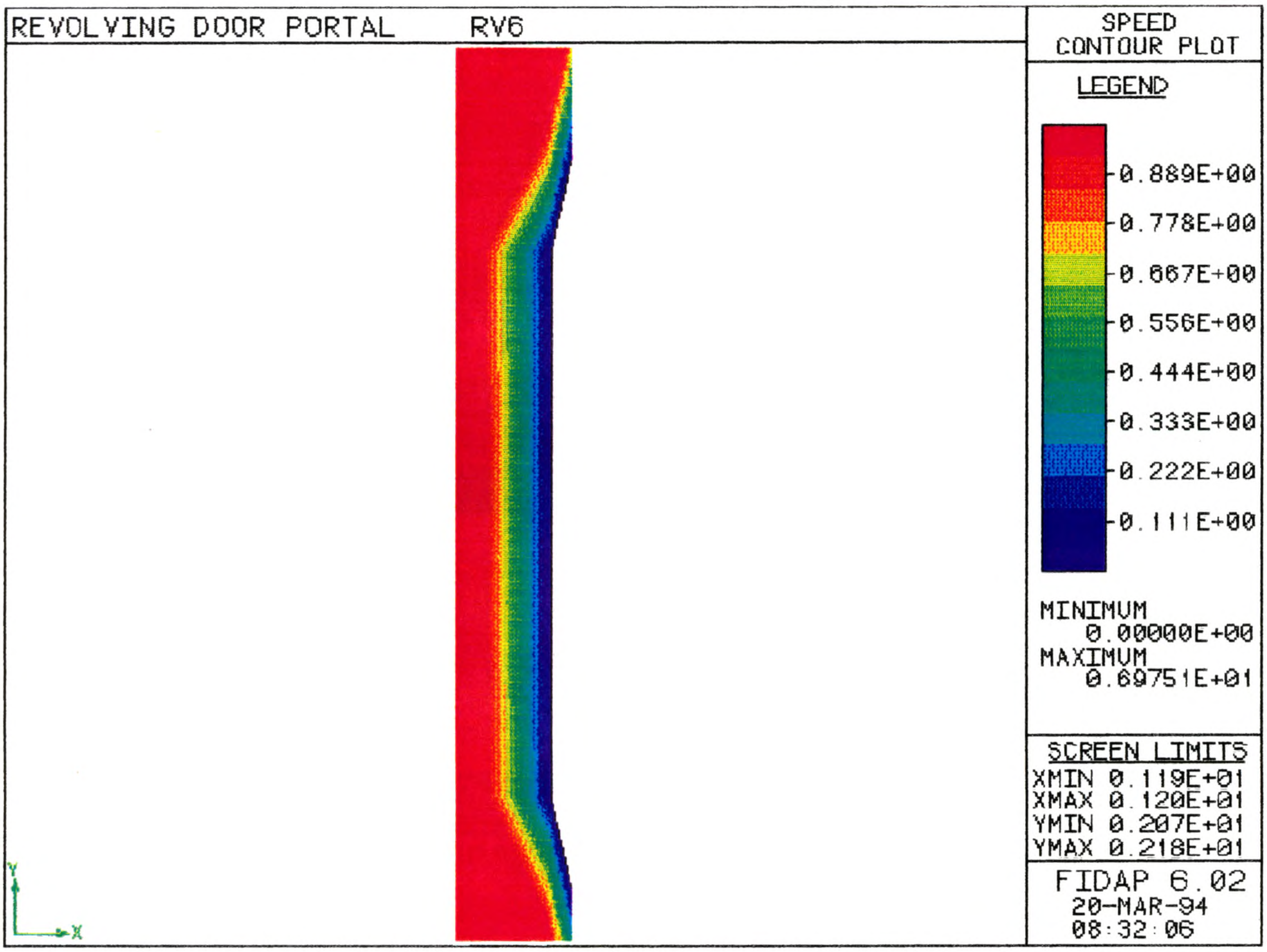

Figure 48: Magnification of the slow-flow layer adjacent to the stagnation point.

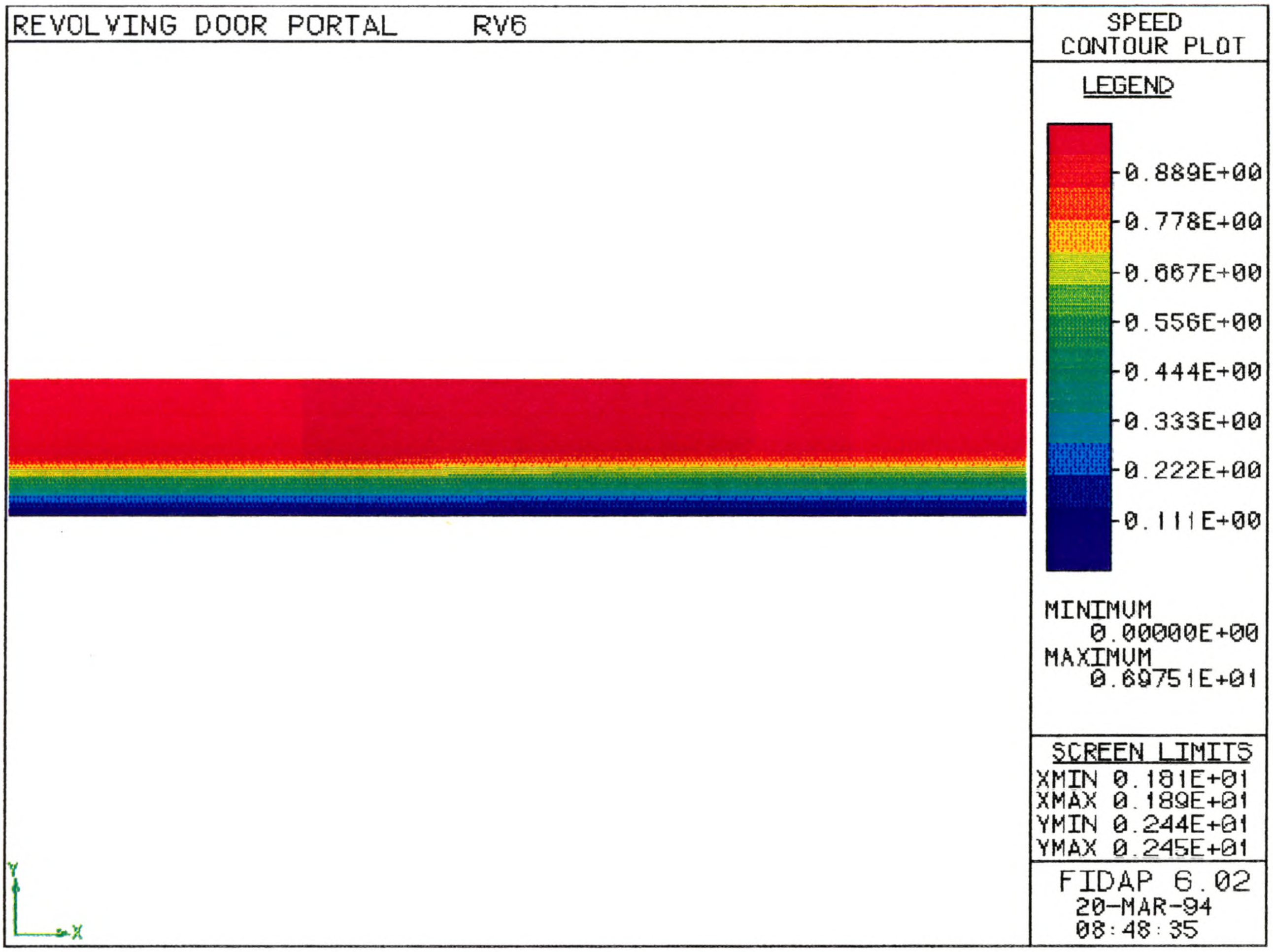

Figure 49: Magnification of the slow-flow layer at the person's front.

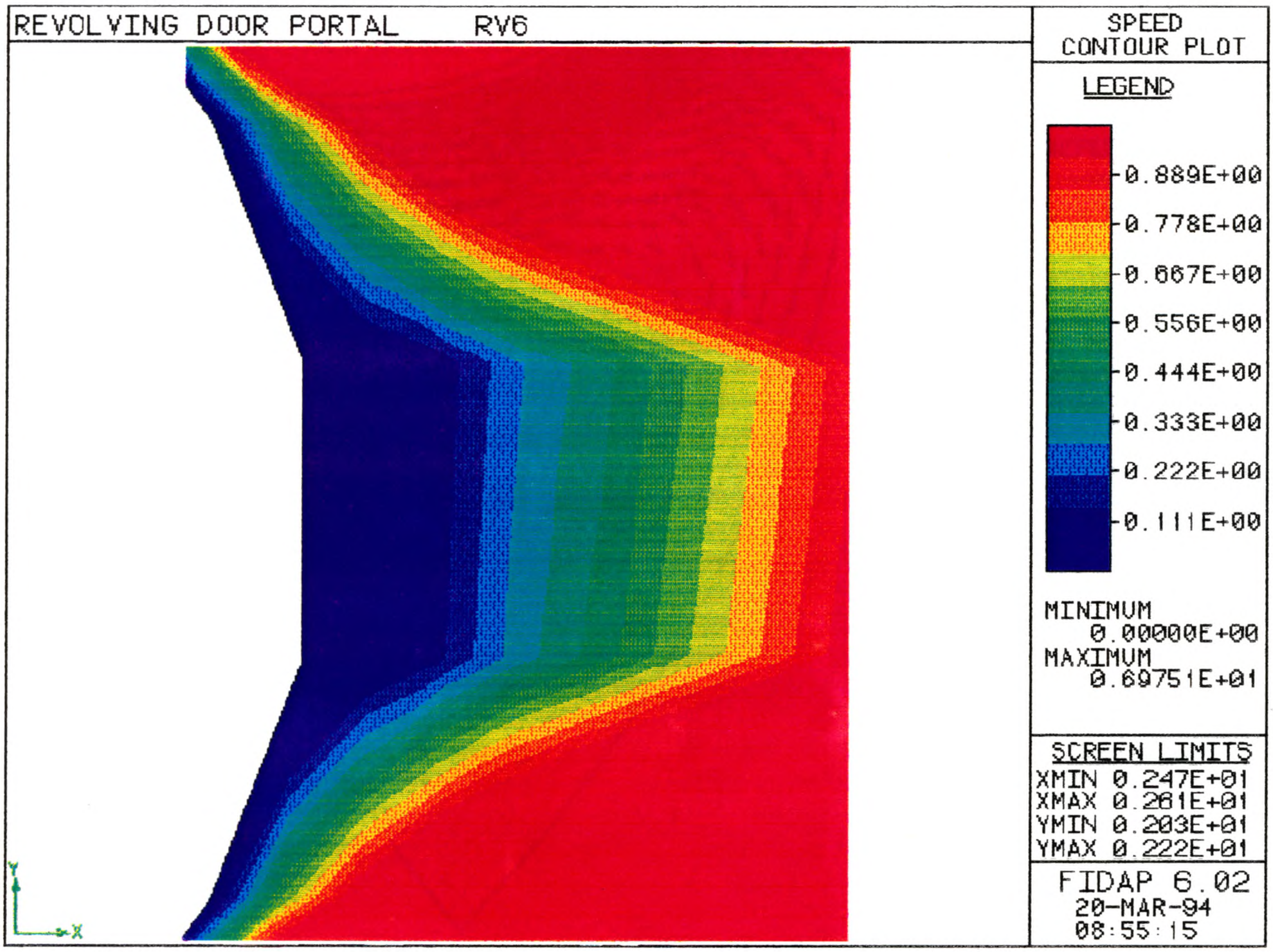

Figure 50: Magnification of the wake.

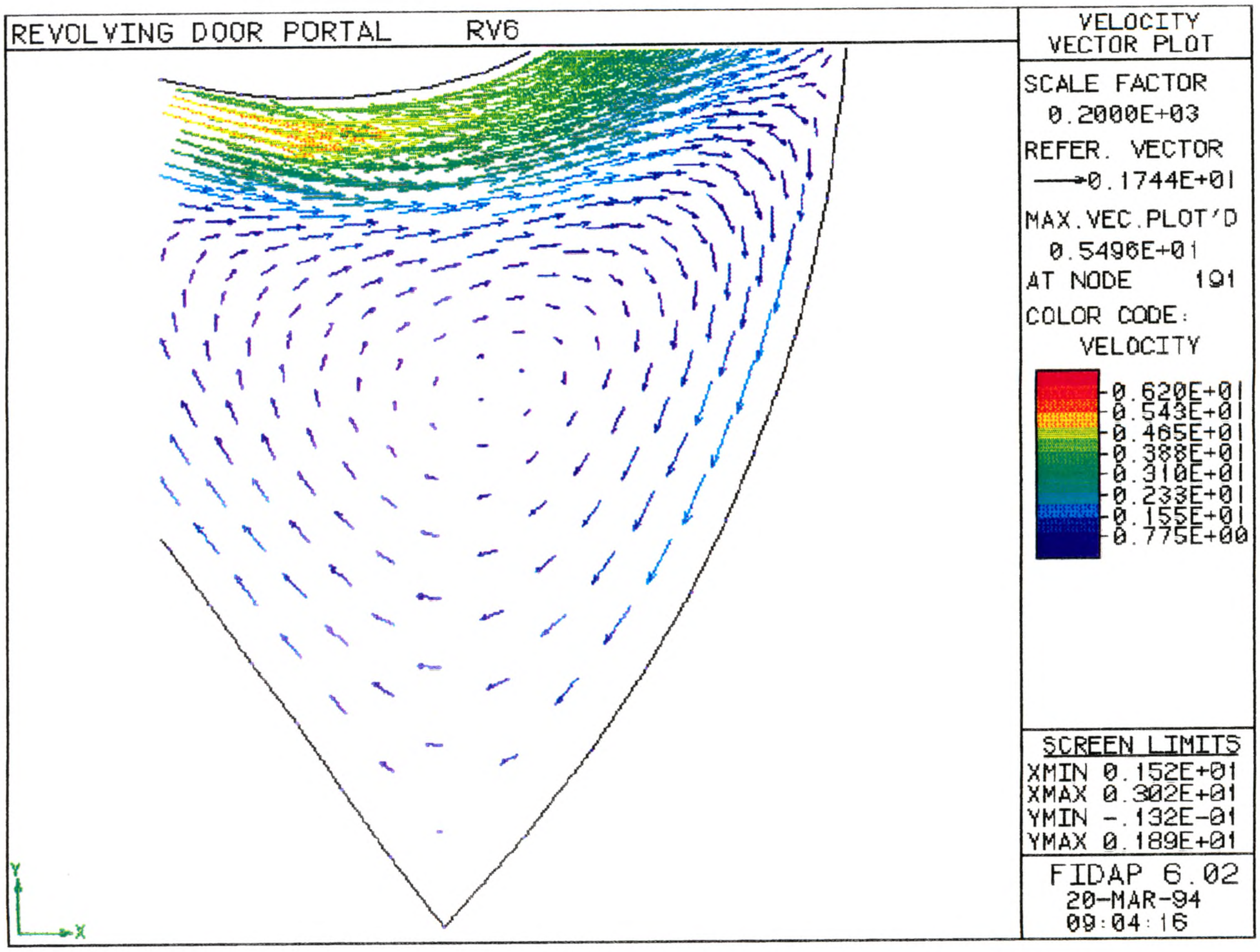

Figure 51: Vector velocity plot of the lower corner of the revolving door portal.

This plot shows a potential problem with this design, since large eddies exist in the corners of the portal. Any explosive vapor which enters these eddies would probably remain for some time. The solution to this problem would be the addition of low-volume blowers somewhere in the corners of the portal, which by correct placement might also reduce the wake.

CONCLUSIONS

- The thickness of the slow-flow zones surrounding a person greatly affects the efficiency of mass transfer.
- In order to detect concealed explosive within 6 seconds, the slow-flow layer must be no wider than 0.2 inch anywhere around the person.
- Stagnation points and wakes are trouble spots.
- Walk-through portals have advantages over walk-in/walk-out portals.
- Walk-through portals with cross-flow are superior to those with axial flow.
- Having two exits pulling air in opposite directions is counter-productive.

- The person must be positioned as near to the exit as possible.

- A wedge-shaped portal and downstream baffles can reduce the size of the wake.
- Using upstream baffles can help reduce the size of the slow-flow layer at the stagnation point.
- Turning a person sideways to the flow greatly reduces the size of the wake.
- A revolving door portal can minimize slow-flow zones and sample dilution. This design, however, may require blowers to break up large eddies in the corners.